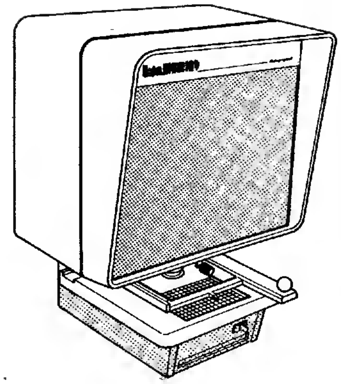
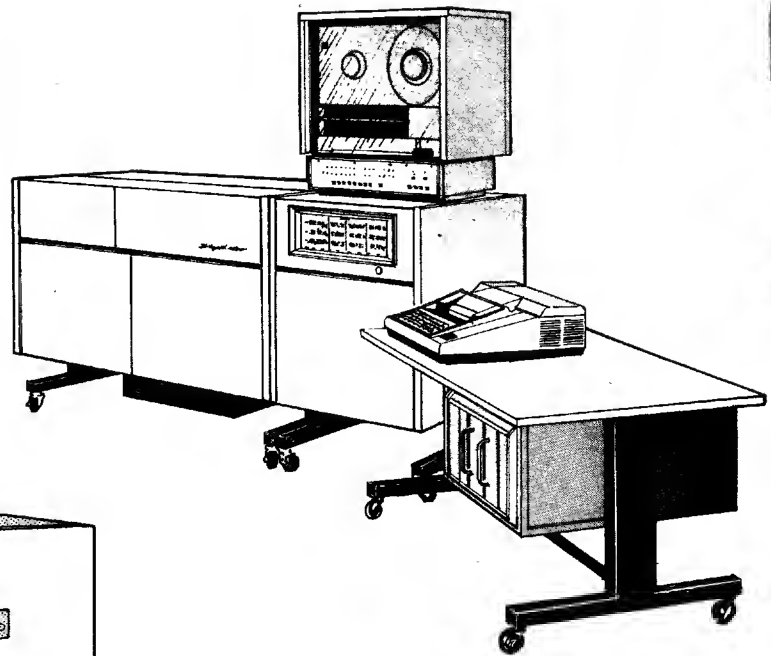
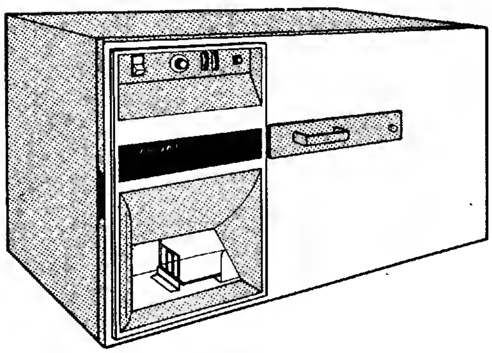
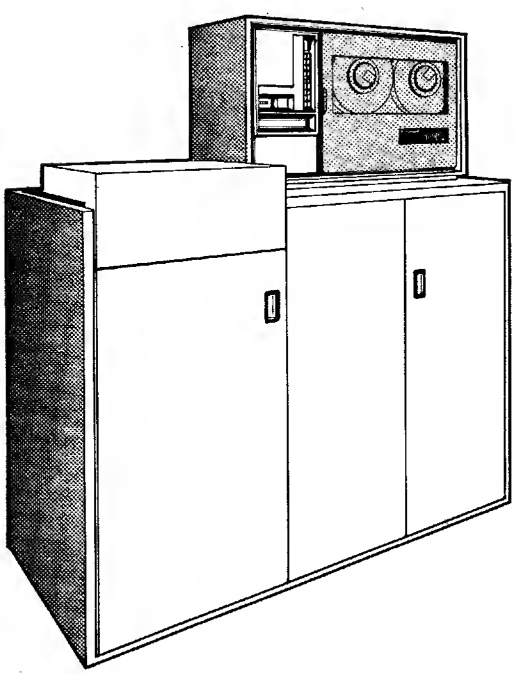
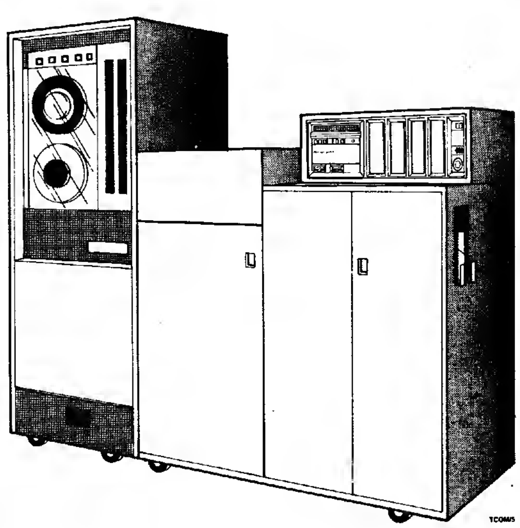






Training Manual





Datagraphix

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

SECTION I

INTRODUCTION

1.1 PURPOSE AND USE OF THIS MANUAL

This manual is designed to provide the new hire employee much of the basic background material necessary to benefit from training at DatagraphiX Training Center.

The manual is written as a series of chapters dealing with a number of basic subjects. The new hire should successfully complete the entire manual prior to attending training sessions.

1.2 HISTORY OF MICROFILM

Perhaps the very beginning of the microfilming industry was in 1839 when John Benjamin Danzer of Manchester, England installed a microscope lens in a camera and actually made a microphotograph of a document. This appears to be the first important date in the history of microfilm.

The father of microphotography is generally considered to be Rene Dagron, however, since he held the first patent. The first patent for microphotography was granted to Dagron by France in 1859.

1.2.1 FIRST PRACTICAL USE

The first meaningful use of a microform was during the siege of Paris by Prussian armies in 1870-71. Microfiche were used by the beleagured French to communicate with the world. Tiny microfiche were flown by carrier pigeons in a "Pigeon V-Mail" service. Information was microfilmed on collodion plates. The plates were then stripped and cut to 36 x 40 mm size that contained up to 80,000 words.

A single carrier pigeon could fly with up to 21 of these films. After a pigeon safely arrived in Paris, each film was sandwiched between glass and then projected on a wall.

By the end of the war, over two and one-half million copied messages had been flown across the German lines.

1.2.2 FIRST BUSINESS USAGE

After World War I, microfilm was called upon to solve important business problems. The development

of a rotary microfilm camera by George McCarthy, a New York City bank clerk and amateur inventor, provided the innovation that opened the way.

The bank clerk had frequently encountered problems when customers claimed their accounts were debited for checks never drawn. Since the bank returned cancelled checks to its customers, it often proved impossible to know if the customer was telling the truth.

McCarthy set out to invent a machine that could make photographic records at high speed of all checks deposited. With an engineer partner, Raymond Hessert helping, they made a machine in which a check conveyor belt was synchronized with a motion picture camera. They applied for a patent in 1925. But, alas, checks on some colored papers did not photograph clearly, nor did signatures in light blue ink.

While bankers showed interest in the ckeck photographing machine, they were not interested enough to purchase it. Hessert grew discouraged, so McCarthy bought him out. Soon after, the amateur inventor's tenacity paid off in storybook fashion. People at Eastman Kodak Company learned of the machine and soon showed more than just interest. Kodak signed a handsome contract with McCarthy involving a lump sum payment, future salary, and royalties. Then Kodak put its engineers to work ironing out the kinks in the check recording machine.

On May 26, 1931, the U.S. Patent Office issued Patent No. 1,805,763 to Mr. George Lewis McCarthy for a "Photographic Apparatus" which was, in reality, the first microfilm camera.

By 1933, there were 700 machines operating in American banks. The machine had, by then, been given the name Recordak.

1.2.3 SUBSEQUENT BUSINESS USAGE

Active commercial use of microfilm in the control of business records outside the banking field was also promoted by the new Recordak Corporation during the thirties. Rotary camera came into use for such purposes as making records of retail receipts in department stores. Stores adopted systems whereby they could mail sales receipts to customers as proof of purchase after making a microfilm record, thus saving considerable paperwork.

For many years, microfilm continued in limited use by banks and department stores mainly for protection.

A new and large scale need for microfilm came in 1936 when the Social Security Act was passed and millions of applications had to be processed. A year later, in 1937, it was decided to put Social Security records on microfilm for protection.

1.2.4 LEGAL ACCEPTANCE

In 1940 a dramatic microfilm milestone was reached when the U.S. Government legalized destruction of documents after they had been microfilmed. Microfilm copies could stand as legal evidence in the courts.

1.2.5 WORLD WAR II USAGE

During World War II, microfilm was used extensively by industry to safeguard engineering drawings. V-mail was introduced during this period and an estimated one and one-half billion letters were filmed and delivered to Armed Forces personnel overseas.

In addition to this, aperture cards were used in intelligence work to a limited degree.

1.2.6 POST WORLD WAR II USAGE

In 1947, the Social Security Administration converted 90 million ledger sheets to a film system with provisions for quarterly updating. This was done by punch card tabulation. This system was so successful that many other government agencies and industrial operations made large scale film conversions. Most of this conversion was on 16mm or 35mm roll film.

The files created were largely manual with retrieval speed dependent on the simplicity of the subject matter and the quality of the indexing.

As the microfilm industry continued to grow, the use of roll film and aperture cards became more automated and the hardware more sophisticated. Cartridge and magazine systems were brought into use by 3M, Bell & Howell and Recordak. Paralleling these systems, other microforms evolved. These included such film forms as microfiche, microjackets, microstrips and non-film forms such as micro-opaques.

1.2.7 COMPUTER INFLUENCE

The advent of the computer brought about the most significant development for microfilm: tying in Micromation recording, storage and retrieval capabilities with computer output to create a complete practical and economical information dissemination system - Computer Output Microfilm (COM).

1.3 HISTORY OF DATAGRAPHIX

Almost thirty years ago, before we had our DatagraphiX name, we were first with a computer driven cathode ray display, and today, we are still first with the largest number of installed COM devices.

The history of COM and of DatagraphiX goes back to Consolidated Vultee Aircraft and its Charactron® Project. Vultee was acquired by General Dynamics and became the Convair Division.

Stromberg Carlson also became part of the General Dynamics family. The Charactron Project was transferred to the Data Projects Division of Stromberg Carlson.

In 1969, the Data Projects Division of Stromberg Carlson split off and became Stromberg DatagraphiX, as a subsidiary of General Dynamics.

Recent times have brought about the single name DatagraphiX, because of our recognition by that name throughout the world.

The first unit similar to what we call COM dates back about twenty-two years. Early models were the 100 followed by the 4010 and then the 4020. The 4020 gained fame because it was both graphic and alphanumeric.

DatagraphiX manufactured and distributed a series of alphanumeric units designated as the 4400, 4440, 4360, and 4200 together with graphic units designated as the 4060 and 4460. The 4360 became well known as the COM unit with the universal camera which made possible roll film and microfiche recording for the first time with one camera.

DatagraphiX then pioneered the unitized modular concept in the 4500 series of COM recorders. The 4530 off-line COM recorder advanced the microfiche state-of-the-art considerable.

The 4550 was soon forthcoming with an exciting mini-computer logic added. Soon to follow were the 4540 and 4560 high-speed camera models. The 4500 COM series established many firsts in the industry. The 4500 off-line COM recorders accept magnetic tape inputs that can be recorded in several formats from a variety of computers. The 4550 and 4560 have expanded capabilities with the mini-computer that provides data formatting and microfiche management using a solid state non-impact teletypewriter for operator interface.

The newest product is the AutoCOM Series of recorders which are available as self-standing, on-line and mini-computer controlled versions. All of which produce cut, fully processed fiche ready for duplication.

1.3.1 COM DEFINITIONS

Various definitions that are needed for this training course are given as follows:

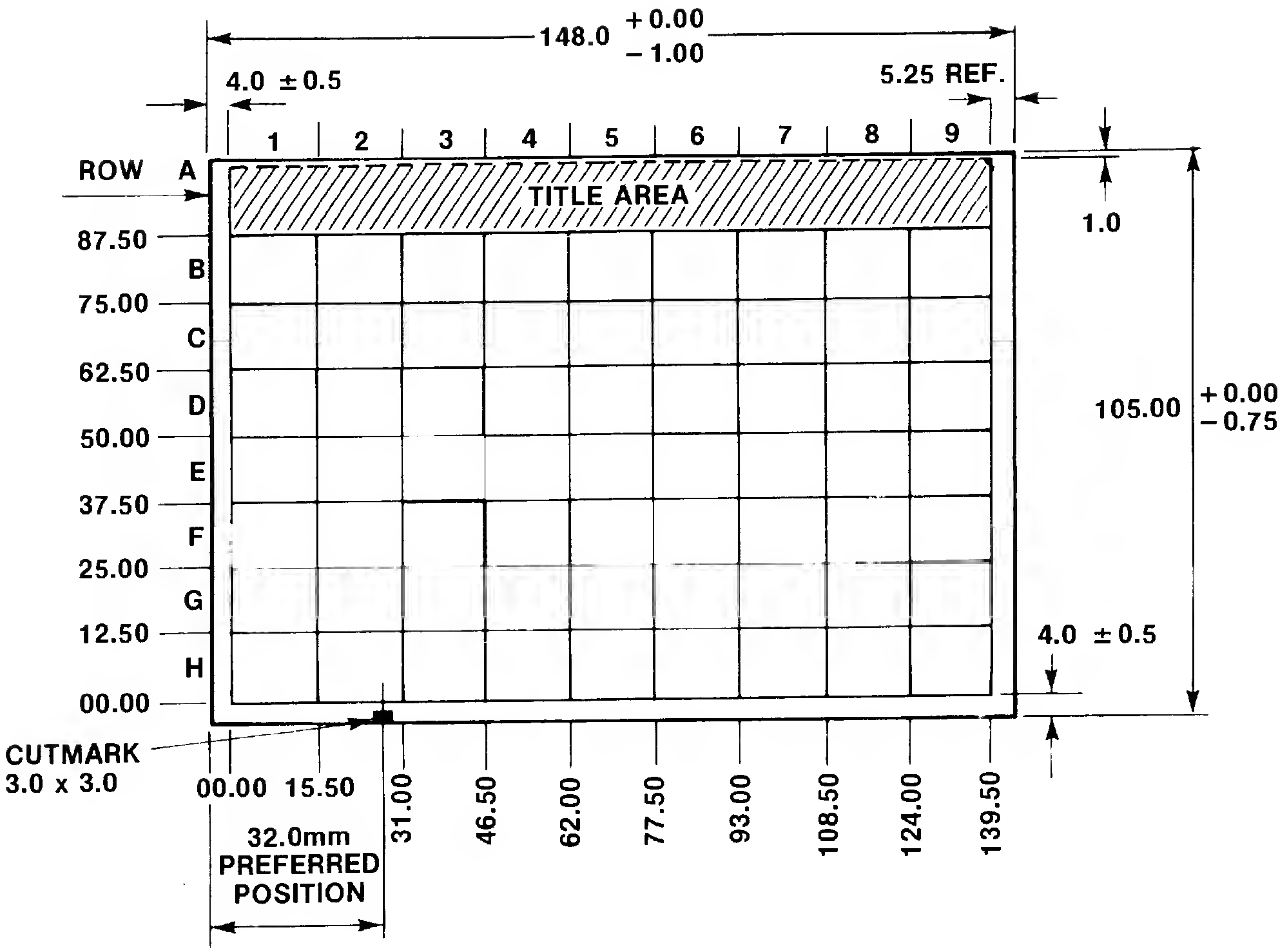
- **MICROFILM** - The NMA (National Micrographics Association) defines microfilm as:

  a. A fine grain, high resolution film containing an image greatly reduced in size from the original.
  b. The recording of microphotographs on film.
  c. Raw film with the characteristics as in (a).

Practically, microfilm is data in a reduced form. Size and weight and quantity of material is drastically reduced compared to hard copy, i.e., paper. Reduction in these areas result in a reduction in:

a. material costs
b. labor cost
c. storage cost
d. mailing (distribution) cost

- FICHE FORMAT



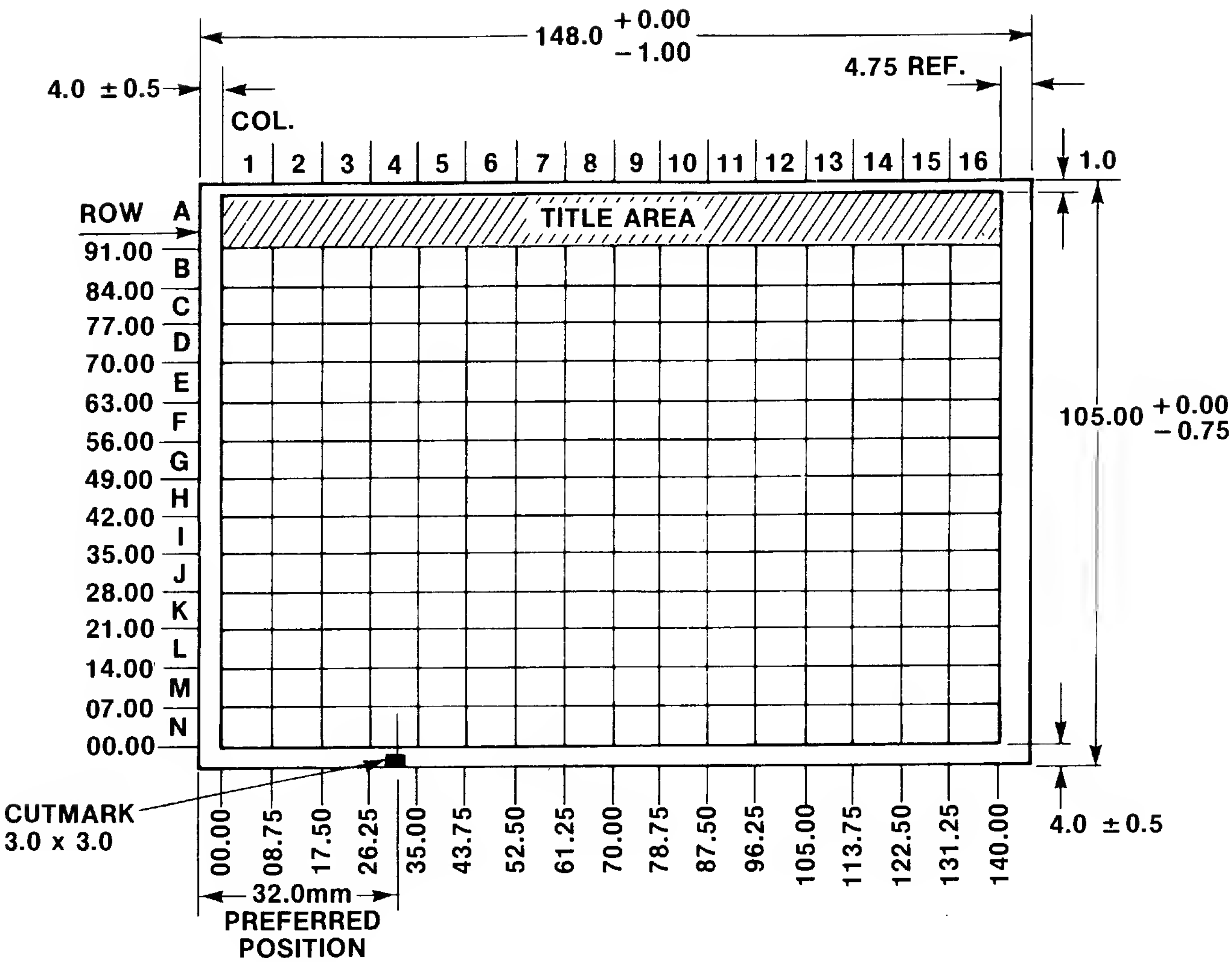
TYPICAL IMAGINARY
SIZE 14″ x 11″
64 LINES, 132 CHARACTERS

NOTES:

1. FORMAT - 9 COLUMNS x 7 ROWS 63 FRAMES
2. EFFECTIVE REDUCTION 24 x ±5%
3. DIMENSIONS IN MILLIMETERS, EXCEPT WHERE NOTED
4. GRID LINES SHOWN DO NOT APPEAR ON MICROFICHE

ACOM/158

Figure 1-1. NMA Standard Microfiche Format: 24X, 11″ x 14″ Page



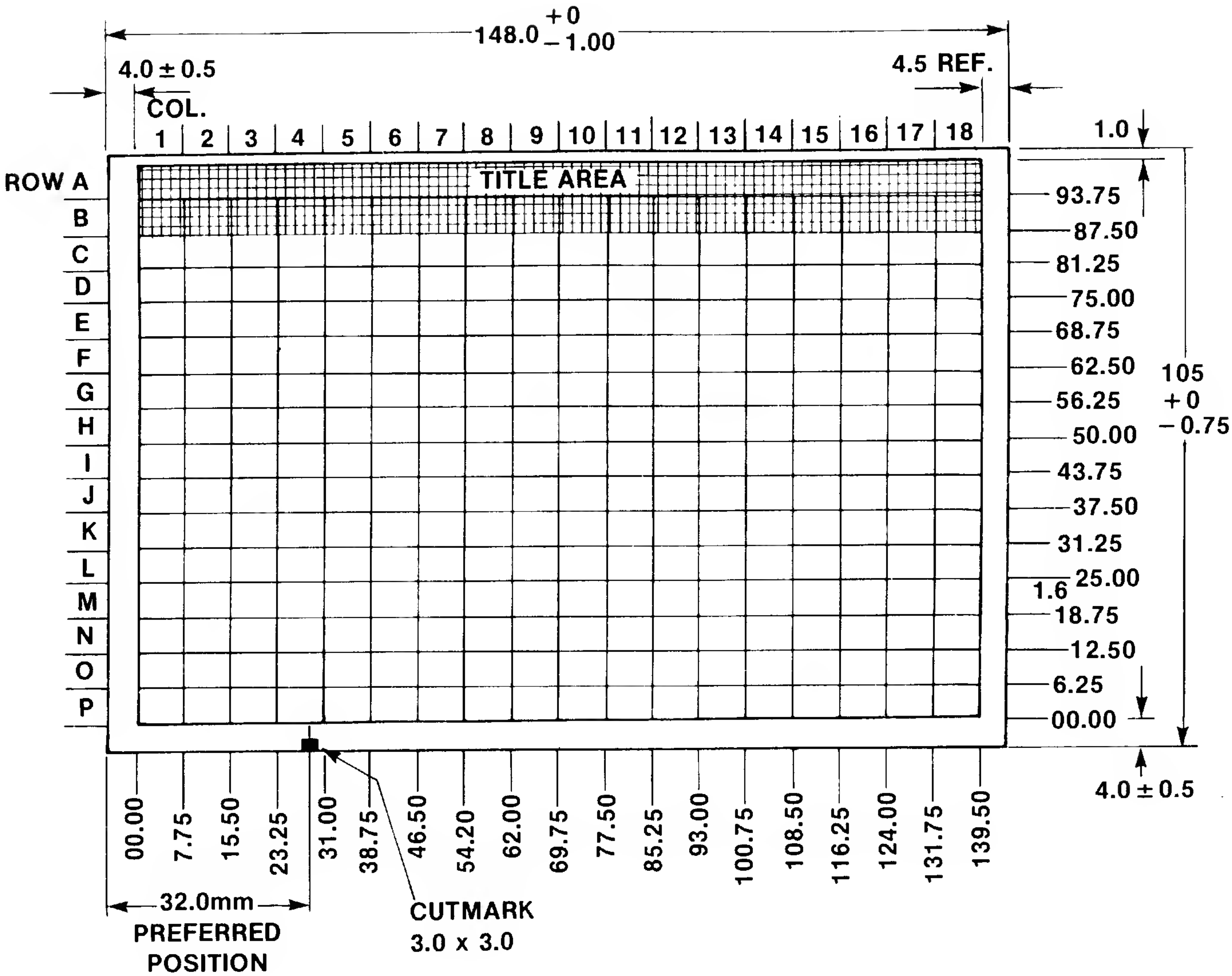
TYPICAL IMAGINARY
SIZE 14″ x 11″
64 LINES, 132 CHARACTERS

NOTES:

1. FORMAT - 16 COLUMNS x 13 ROWS 208 FRAMES
2. EFFECTIVE REDUCTION 42X x ±1X
3. DIMENSIONS IN MILLIMETERS, EXCEPT WHERE NOTED
4. GRID LINES SHOWN DO NOT APPEAR ON MICROFICHE

ACOM/159

Figure 1-2. NMA Standard Microfiche Format: 42X, 11″ x 14″ Page



TYPICAL IMAGINARY DOCUMENT
SIZE 14″ x 11″
64 LINES, 132 CHARACTERS

NOTES:

1. FORMAT - 18 COLUMNS X 15 ROWS 270 FRAMES.
2. EFFECTIVE REDUCTION 48X ± 1X.
3. DIMENSIONS IN MILLIMETERS EXCEPT WHERE NOTED.
4. GRID LINES SHOWN DO NOT APPEAR ON MICROFICHE.
5. ROW "B" MAY ALSO BE USED FOR HEADING.

ACOM/160

Figure 1-3. NMA Standard Microfiche Format: 48X, 11″ x 14″ Page

- **N.M.A.** - (National Micrographics Association) is an industry group which has established standards for the formats of recorded microfilm data. The film formats we are concerned with are for microfiche. Microfiche is a sheet of microfilm containing multiple microimages in a grid pattern. Each microfiche usually contains a title which can be read without magnification.

  A microimage is a unit of information, such as a page of text or a drawing, too small to be read without magnification. DatagraphiX equipment is constructed so that the microfilm produced conforms to **N.M.A.** standards.

- **COM** - COM is a specialized field **N.M.A.** defines as:

  a. **Computer Output Microfilm** - microfilm containing data produced by a recorder from computer generated electrical signals.

  b. **Computer Output Microfilmer** - A recorder which converts data from a computer into human readable language and records it on microfilm.

  c. **Computer Output Microfilming** - A method of converting data from a computer into human language in a readable format, then into microfilm. Computer output microfilm is what we are concerned with during the remainder of this course of instruction.

- **REDUCTION RATIOS** - Reduction is the number of times a linear dimension of an object is reduced when photographed. COM reduction ratios and formats are based on the "standard 11 x 14 -7/8 inch computer line printer page" which has 132 characters per line spaced 6 lines-per-inch, which yields 64 lines-per-page." The height of each character is 0.10 inch. The normal reduction ratios then yield approximate page sizes of the microimage as follows:

Reduction Ratio	Page (Frame) Size	Character Height
24X	.44 x .60"	.004"
42X	.262 x .357"	.0023"
48X	.229 x .312"	.00208"

All published N.M.A. standards are in terms of metric measurements as in the following:

Reduction Ratio	Frame (Page) Size
24X	12.5 x 15.5mm
42X	7.0 x 8.75mm
48X	6.25 x 7.75mm

- **MICROIMAGES** - The pages of microfilm data are viewed via a magnifier. Usually the image is enlarged back to approximately 75% of the nominal original size, which is about an 8 x 10 inch viewing screen.

SECTION II

SILVER FILM

2.1 THEORY OF SILVER FILM

Conventional silver film is fast enough to record data being placed on the face of a CRT. It has excellent quality and has worldwide recognition as a recording medium. However, there are disadvantages, such as:

- Sensitivity to room light
- Relatively long development times
- The use of development chemicals considered toxic
- The care required in handling
- The procedures required to get archival permanence

Much research is being carried out to develop film that can be handled easily in room environment, is fast enough to record CRT data and is easily developed. Dry silver is one method actually in use today that records CRT output and is developed by heat.

2.1.1 SILVER HALIDE IMAGING

Silver Halide photographic materials form images from the photochemical reaction that occurs when light is absorbed by silver halide. Silver photographic films consist of a dispersion of silver halide granules in a media such as gelatin (emulsion) coated on a transparent backing material such as glass or cellulose acetate butyrate. The emulsion coating is approximately 0.0004 inches thick.

Light sensitive compounds of silver halides and salts that produce silver images are uniformly dispersed in the emulsion coating. On exposure to light, radiant energy is absorbed which creates a latent image that can be seen after chemical developing. When exposed film is placed in a developer, the solution reacts with the exposed grains containing the latent image material. The silver is freed from its compound and is deposited as tiny, irregular grains of metallic silver. These grains of metallic silver form the image.

2.1.2 FILM STRUCTURE

The general structure of silver film is shown in Figure 2.1.

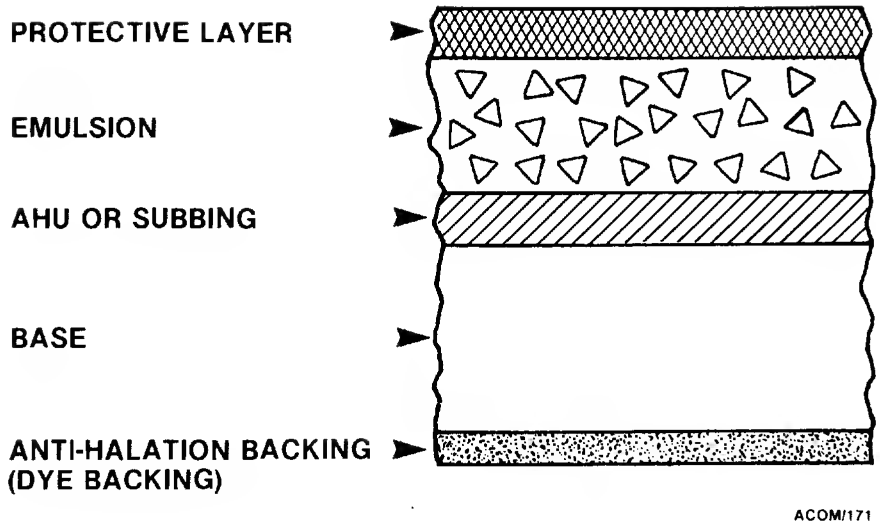


Figure 2.1. Simplification of Film Cross Section

2.1.2.1 Protective Layer - The protective layer (usually clear gelatin) is clear material used to reduce the abrasion or staining of the emulsion.

2.1.2.2 Emulsion Layer - The photographic emulsion is not really a true emulsion, but rather, is a dispersion of crystalline silver halide in a colloid. The term emulsion has been in use so long, however, and is so generally understood, that the distinction is largely academic. The silver halides used are chloride, bromide and iodide. The silver halide is produced by adding silver nitrate to a solution of the halide, i.e., potassium bromide in a solution of gelatin.

In the absence of gelatin, the crystals of silver halide precipitate and settle to the bottom, but in gelatin, the crystals remain uniformly distributed in the solution. The photographic emulsion is thus a suspension of crystalline silver halide in gelatin.

2.1.2.2.1 Gelatin Characteristics - The superiority of gelatin over other colloids is due both to its physical properties and to its influence on the sensitivity of the silver halide. Indirectly, gelatin is important to the light sensitivity of the silver halide.

The sensitivity of crystals of pure silver halide is comparatively low regardless of the halide or the size of the crystal. The sensitivity of photographic emulsions is due to the formation of sensitivity centers on the silver halide crystals from the decomposition of substances found in gelatin.

Gelatin has the disadvantage that it is of animal origin and, therefore, subject to unordered variations. Gelatin is also costly to produce in a highly refined condition and is subject to attacks by animal and vegetable organisms, insects and bacteria. However, no better material has yet been found.

2.1.2.2.2 Silver Halide Grain - The usefulness of present day photographic materials is a result of the tiny individual particles of silver halide which are suspended in the gelatin. These particles are extremely sensitive to light and store up the effect of an exceedingly small amount of light. This effect

can, in turn, be multiplied by the action of the developer. This stored-up effect of light is known as the latent image and it is so small that it cannot be detected by any means other than by development itself. Therefore, the nature of the latent image and the nature of development processes are closely related. An understanding of these processes requires a knowledge of the structure of the silver halide grains themselves. The uniqueness of silver halides in a photo process is that the absorbtion of a few photons leads to the formation of millions of silver atoms by the amplification of the development process.

Silver halide grains are minute crystals that are completely insulated from each other by gelatin. All emulsions contain a range of grain sizes but the average size within a given emulsion ranges from exceedingly small (0.1 micron) in slow emulsions to several microns in fast emulsions.

Grains are then platelets with triangular, hexagonal and a variety of other shapes, in addition to their normal crystal structure.

2.1.2.3 Subbing Layer - The subbing layer is clear adhesive which holds the emulsion to the base.

2.1.2.4 Base - The base consists of material used to support the emulsion and backing. The most common base stocks are cellulose acetate propionate, cellulose acetate cutyrate and polyester (mylar).

The requirements of a satisfactory film base are exacting as indicated by the following:

A. **Optical requirements**

- Transparent
- Free from haze and visible imperfections
- Colorless

B. **Chemical requirements**

- Chemically stable
- Inert to highly sensitive emulsions
- Good adherence of the emulsion layer
- Unaffected by photographic chemicals
- Moisture resistant

C. **Physical requirements**

- Strong, tough and hard, but not brittle
- Stiff but flexible
- Elastic and plastic properties
- Tear resistant
- Free from curl, buckle, etc.
- Dimensionally stable

D. **Thermal requirements**

- High softening temperature
- Slow burning

2.1.2.5 Backing - The backing is material to reduce reflected light (antihalation) or to reduce static electricity (anti-static). Both may be part of the film. The DatagraphiX silver film has an anti-static backing but no anti-halation backing. DatagraphiX silver film has an anti-halation undercoat, see Figure 2.5.

The halation seen in films is the result of light scattering (reflected) off the backing and imaging the film. Figure 2.2 shows a typical light scattering in a silver film without halation protection.

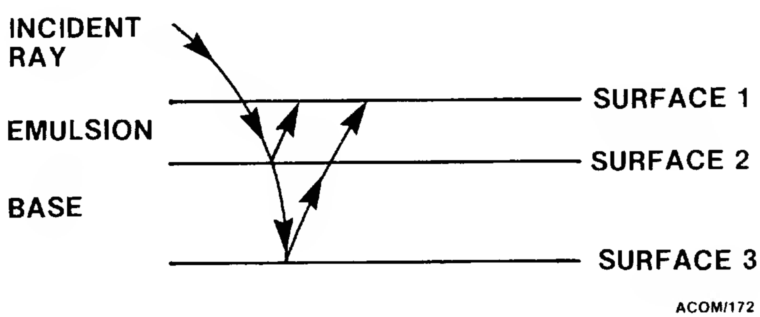


Figure 2.2. No Halation Protection

The light is refracted at the base, Surface 2, and is internally reflected at Surface 3, back to the emulsion where the silver is exposed. The purpose of the anti-halation undercoat or anti-halation backing is to attenuate the intensity of this refracted-reflected ray so there is no secondary exposure. Figure 2.3 gives the picture of a film with an anti-halation backing.

Different types of backing are used in practice. A commonly used anti-halation backing has a dark blue appearance. Other films also frequently have a black carbon backing called "rem jet" backing which has to be scrubbed off mechanically and pollutes the developer. Since they look alike, one should take care not to confuse the two types.

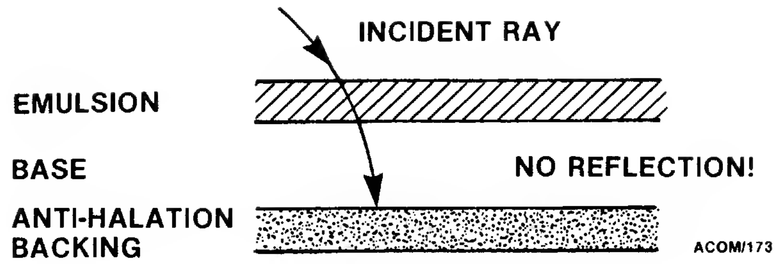


Figure 2.3. Anti-halation Backing

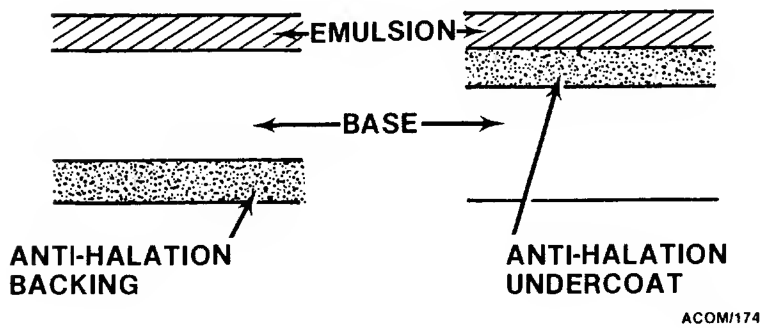


Figure 2.4. Halation Protection (Anti-Halation backing)

Figure 2.5. Halation Protection (Anti-Halation undercoat)

Antihalation backing requirements are such that the dye for anti-halation must meet the following requirements:

- High light absorption, particularly in the region of maximum emulsion sensitivity.
- No effect on emulsion or film base under ordinary storage conditions.
- No effect on the process of development.
- Completely bleached or removed either in the developer or fixing bath, preferably the developer.
- No undesirable residual products left on the film after ordinary fixing, washing, and drying.

2.1.3 DATAGRAPHIX FILM

The base stock is usually manufactured from mylar (polyester) or triacetate material. Each base material has some advantages over the other when used in DatagraphiX equipment. Mylar is a very strong material and demonstrates high dimensional stability. Mylar is also very stable under relative humidity and temperature changes which make it desirable for a film base. However, triacetate base films are commonly used in DatagraphiX systems because they are less susceptible to static. Triacetate base films are not as susceptible to static as mylar. One last advantage that acetate has over mylar is low light piping. This phenomena can be visualized as light entering the edge of the film and being transmitted without much attenuation toward the center of the film.

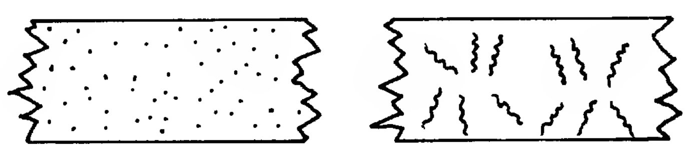
2.1.4 FILM PROBLEMS (CURL AND STATIC)

It should be clear that trying to image a non-flat film or make hard copy from a non-flat film causes the image to be distorted. Film curl is found to some degree in all silver halide films. A film that is absolutely flat has a curl of zero. By convention, a positive curl means that the edge of the film is bent toward the emulsion side and negative curl means the edge of the film is bent toward the base. Curl can result from an environment that has caused stress between the emulsion and the base.

Holding the emulsion onto the base is an adhesive. If the base expands at a different rate than the emulsion for some given change in temperature or humidity, the film curls. This situation can be commonly found in a bi-metallic strip. Most films have been optimized at 70°F, 50% R.H. for curl (i.e., curl = zero at 70°F and 50% R.H.). If the film is taken below the optimized conditions 'reverse' or negative curl results.

Improper storage temperature or too high a drying temperature can also cause film to curl.

Static exposure is another problem commonly encountered. When film is unwound from a roll at high speed and transported through a camera, the residual static charges eventually discharge and the static electricity exposes an area of the film. Static exposure takes the form of "lightning bolt shapes or small dots, depending on the direction of the discharge". Figure 2.6 illustrates the two most commonly seen static discharges.

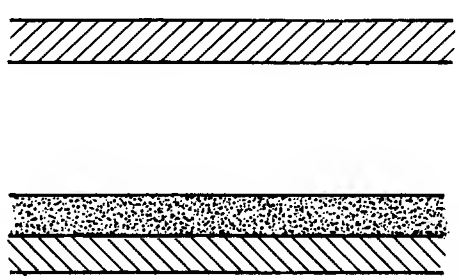


ACOM/175

Figure 2.6. Static Discharges

Static electricity is easily generated in a dry atmosphere: example - leather soled shoes across a nylon rug . . . and a touch of a door knob.

The same is true of film. Under low relative humidity conditions, (below 35% R.H.), the film tends to generate and discharge electricity, resulting in unwanted exposures. Most films put conductive layer either on the back or underneath the emulsion. This layer helps to dissipate the charges instead of letting them accumulate and discharge. Figure 2.7 illustrates the film with anti-halo backing and anti-static protection.



ACOM/176

Figure 2.7. Film Cross-section (anti-halo and Anti-Static Protection)

2.1.5 MICROFILM STORAGE

In storing microfilm, there are two degrees of permanence:

- **Commercial permanence** - does not need to extend beyond a period sufficient for general business purposes.
- **Archival permanence** - preservation which is to be carried to the maximum period obtainable.

2.1.5.1 Effects of Storage

For commercial permanence:

- Temperature - not to exceed 100°F
- Relative Humidity - 25% to 60%

For archival permanence:

- Temperature - 60° - 80°F
- Relative Humidity - 40% to 50%

Storing film at temperatures above 100°F reduces the pliability of the film. If stored below the temperature of the handling room, the film must be brought to room temperature before it is removed from the container.

Prolonged exposure to relative humidity above 60% damages or destroys the gelatin because of growth of mold, and eventually causes the back to stick and buckle. Exposure to a relative humidity below 25% causes brittleness and electric charges which attract dust.

SECTION III

STANDARD AND REVERSAL PROCESSING

3.1 INTRODUCTION TO STANDARD AND REVERSAL PROCESSING

We are concerned with conventional black and white film processing in this study. We also assume that only two kinds of film are involved: film with dark characters and clear background, and film with clear characters and dark background.

It is common to hear terms like negative processing and positive image or reversal processing. These are confusing unless the terms and processes are thoroughly understood.

Begin by looking at the image on the tube face. The characters are bright and the background is dark. Processing a film copy in a standard negative process of developer, fixer and wash, the film has dark characters on a clear background since the film has used light rays to make the characters dark. The blackness of each character image is directly proportional to the amount of silver that is in the film.

Now, with the same film using a reversal process, we get a film with clear characters and a dark background. This film is said to be reversal film.

Of the two types of processes (negative and reversal) negative processing is easier to understand. The first solution in negative processing is the developer. It is not possible here to describe all the properties of developers, but basically the following criteria have to be met. The developer must:

- Reduce silver ions to metallic silver
- Reduce exposed silver-halide grains at a higher rate than the unexposed silver-halide grains
- Be fairly soluable in water and alkaline solutions
- Be reasonably stable and have resistance to aerial oxidation
- Be colorless and soluable oxidation products
- Be innocuous and non-toxic

For DatagraphiX applications, the first and fourth items are most important, although all items are desirable.

The emulsion contains a silver-halide compound which is sensitive to light. The purpose of the developer is to make the image visible to the eye. To do this, the silver-halide must be reduced to metallic silver. Chemically, this requires the developer modecule to give up one or more electrons to reduce the silver-ions.

3.1.1 THEORY OF DEVELOPMENT

The development of the photographic latent image is essentially the reduction of grains of exposed silver halide to metallic silver.

$$Ag^{+} + \text{Electron} = \text{Ag (metal)}$$

During normal development, exposed grains containing a latent image are reduced at a far more rapid rate than unexposed grains. If development is extended for a longer period of time, all grains are developed. Thus, the development of the latent image is a rate phenomenon with the development of the exposed grains taking place at a faster rate than the development of the unexposed grains.

In order for a reducing agent to be a developer, it must fall within the proper range of reducing power. If it is too weak a reducing agent, it cannot reduce silver halide at all, and if it is too strong, it immediately reduces the unexposed grains as well as the exposed grains.

In addition to the ability to differentiate between exposed and unexposed silver halide, a developing agent, to be practical must:

- Have sufficient energy to develop the latent image adequately
- Be free from tendency to fog
- Be reasonably stable in solution
- Be soluble in water or in the presence of sulfide or an alkali
- Not soften the gelatin layer
- Have characteristics that do not vary greatly with changes in temperature, dilution or composition
- Be non-toxic

3.1.2 DEVELOPING ACTION

When the exposed film is placed in the developer solution, the developer attacks the exposed grains which contain the latent image material, freeing the silver from its compound and depositing it as tiny, irregular grains of metallic silver. The developer also attacks the unexposed areas so that a relatively small amount of fog is formed under normal development conditions.

Quality of the development process principally depends on four factors that must be rigidly controlled if a high degree of quality is to be achieved.

- Temperature of fluids
- Agitation of chemical solutions
- Time of development
- Degree of chemical freshness or exhaustion

The relation between the development of fog, as measured by the relationship to the respective densities, is termed the selectivity of the developing agent. This characteristic, depends upon the conditions under which the developer is used, the formula, and the degree of development.

3.1.3 DEVELOPER TEMPERATURE

The rate of development is affected by temperature. As temperature increases, the rate of development increases.

Low temperature for normal time = underdevelopment. High temperature for normal time = overdevelopment.

At high temperature, the gelatin of the emulsion becomes swollen and tender and is easily damaged and may loosen from the support. This is called reticulation and causes fine line wrinkles in the silver.

3.1.4 DEVELOPER AGITATION

If the exposed film is allowed to develop without agitation of the developer solution, the developing power of the solution in contact with the emulsion becomes exhausted. When agitated, fresh portions of solution are constantly brought to the emulsion surface so that the rate of development remains constant and does not allow mottle or density streaks to form.

3.1.5 DEVELOPER TIME

When the exposed material is placed in the developer, the solution penetrates the emulsion reducing the exposed Ag crystals to metallic silver. The longer the development, the more Ag is formed and the blacker the image. The maximum density and minimum density increase. If carried on too long, the developer may begin to act on unexposed silver crystals and cause "developer fog".

3.1.6 DEVELOPER DILUTION

Slight dilution of the developer affects principally the time of development. The variation in time of development is more marked with those developers which oxidize readily. Fog tends to increase due to increased oxidation. The developer solution becomes slower in action as a result of:

- Depletion of the developing agent
- The restraining effect of by-products of the process of development (sodium bromide, - iodide).

3.2 DEVELOPING SOLUTIONS

A typical developing solution contains a solvent, developing agent, preservation, an alkali and a restrainer.

3.2.1 SOLVENT

The solvent used in film development is water. Normally, hard water causes no photographic effect and can be used without special consideration. However, metallic or sulphur content or the presence of granular content would indicate a necessity to filter the water in order to maintain good developmental quality.

3.2.2 DEVELOPING AGENT

The developing agent, normally metaquinone or hydroquinone, is a mild reducing agent. The developer is oxidized and the silver reduced to metallic silver.

3.2.3 PRESERVATIVE

All organic developing agents have a strong affinity for oxygen and require additive agents for stability.

The preservative addition of sulfide:

- Protects organic developing agents against aerial oxidation
- Prevents the formation of straining developer products
- Acts as a silver halide solvent by the formation of complexes
- Is a weak alkali and under certain conditions increases the rate of development and the maximum density obtainable

Insufficient amount of the preservative results in rapid oxidation of the developer causing:

- A loss in developing power
- Formation of colored oxidation products which stain the gelatin
- Oxidation fog

Large amounts of the preservative improve the keeping properties of the developer but increase the time of development and reduce the effective emulsion speed throughout the solvent action on silver bromide.

3.2.4 ALKALI

The function of the alkali is to increase the ionization of the developing agent and to absorb the bromide liberated in development. The alkalies in general use include the alkaline carbonates, cuastic alkalies, borates, etc.

3.2.5 RESTRAINER

The addition of potassium bromide is ordinarily for the purpose of preventing fog. Whenever maximum contrast is required, a relatively high concentration of bromide is usually necessary. The effect of adding restrainers varies with the developing agent and is greatest with those of low potential.

3.3 CARE OF DEVELOPER SOLUTIONS

The loss in density and contrast due to partial exhaustion of the developing solution may be overcome to a certain extent by adding a replenishing solution. This may be either a solution of the same composition as the original formula or a more concentrated solution.

Replenishment compensates for the developer user during the developing process. Developers cannot be replenished indefinitely because of the accumulation of silver sludge, dirt and gelatin.

3.3.1 DEVELOPER TESTING

Testing of the developer is of value for:

- Maintaining uniformity of processing through the use of standardized solutions
- Determining the source of unusual behavior, i.e., fog, etc.

For most purposes, comparative photographic tests are adequate. The step wedge is easily used for comparisons and are more easily and accurately made. Comparisons should be made visually of the following:

- Fog
- Threshold value (the first exposure producing visible density)
- Density scale and progression

3.3.2 DEVELOPER FOG CAUSES

Developer fog may be produced by the following:

- Solution improperly compounded - dilution
- Excessive solution temperature
- Excessive developing time
- Solution contaminated with metallic salts
- Solution contains sodium sulfide as a result of the reduction of the sulfite to sulfide by bacterial or fugus growths
- Exposure of film to air during development (oxidation fog)

3.3.3 DEVELOPER STAIN

Stains usually have a metallic appearance in reflected light and a reddish or purplish color in transmitted light. Stain is frequently termed dichroic fog. Stain from developers may arise with:

- Excessive oxidation
- Excessive temperature
- Excessive exposure to air during development
- Use of old developer

3.4 THEORY OF FIXING

After the development process, the undeveloped silver halide must be removed to keep it from obscuring the image. The emulsion is now treated in the fixing process which reduces the unexposed silver halide to neutral salts which are removed from the film.

The function of a fixing agent is rather limited and the requirements are as follows:

- It should dissolve silver halides without affecting the silver image
- It should be readily soluble in water yet stable
- It should not cause excessive swelling or softening of gelatin

The most important fixing agents are sodium and ammonium thiosulfates, lithium thiosulfate and guanidine thiosulfate. If fixing is incomplete, no amount of washing can render the image permanent and the unreduced silver compounds remaining in the film will discolor with the passage of time.

3.4.1 ACID FIXING AND HARDENING BATH

The acid fixing and hardening bath usually contains:

- A solvent of silver halide - Hypo.
- Anti-staining agents
- Preservative - Sodium Sulfide
- Hardening Agent - Alum

3.4.2 FIXING PROCESS EXHAUSTION

The principle changes leading to exhaustion of fixing are:

- The concentration of hypo is reduced and silver accumulates in the solution. In time, these accumulates decompose to form a yellow-colored stain that consists chiefly of silver sulfide.

- Alkaline halides accumulate in the bath. Sodium bromide and silver iodide forms and retards the rate of fixing.

- The pH of the bath is reduced by the developer brought in by the wet film. A sludge of aluminum sulfate forms and the bath no longer hardens the gelatin satisfactorily.

A fixing bath used near to the point of exhaustion forms complexes that are absorbed by the silver grains and the gelatin and cannot be removed by washing. They eventually discolor and stain and are not easily removed.

For practical purposes, a fixing bath may be regarded as exhausted when a few drops (3-4) of a 10% solution of potassium iodide added to 25cc of the fixing bath causes a yellow precipitate to form.

3.4.3 RATE OF FIXING

The time required for the fixing process varies for the following reasons:

- **Nature and thickness of the emulsion**. Large grain emulsions fix more slowly than fine grain emulsions. Emulsion containing silver iodide fix more slowly than those of silver bromide and these, in turn, more slowly than emulsions of silver chloride.

- **The composition of the fixing bath**. As the fixing bath becomes less concentrated, the fixing time increases.

- **The temperature**. As the temperature increases, the fixing time decreases.

- **Agitation**. Agitation of the solution reduces the fixing time.

3.5 REASONS FOR WASHING

The fixing process converts the insoluble silver halides into soluble compounds which are removable in washing. Washing also removes the fixing agent and its oxidation products from the emulsion. These, if left, would slowly combine with the silver image to produce a brown-yellow stain of silver sulfide, usually with some loss in density.

3.5.1 TIME REQUIRED FOR WASHING

The time required for washing depends on:

- **The efficiency of washing** - The more rapid the change of water in contact with the gelatin layer, the less time required for washing.
- **The composition of the fixing bath** - The washing time varies with the effectiveness of the fixing bath.
- **Temperature of the wash water** - Washing efficiency increases rapidly with an increase in the temperature of the water.
- **The pH of the wash water** - Increasing the pH value from 7 to 11 increases the rate of washing.
- **Extent to which the hypo must be removed** - Archival quality washing is more thorough and takes longer. It varies the safe concentration of residual hypo or thiosulfate on the film from 0.005 to 0.10 mg. per square inch. This is for film storage of 50 to 100 years.

3.5.2 TESTS FOR RESIDUAL HYPO

The presence of hypo on the film may be detected from the discoloration of an alkaline solution of potassium permanganate, or an iodine-starch solution. The latter is more sensitive, but both procedures only indicate the presence of hypo in the water draining from the surface of the film.

The Crabtree test is currently the best test for the presence of residual hypo on the film and is extremely sensitive. An actual sample of the film is used, not just the water in the test. A new test is being developed called the "methylene Blue" test which is even more accurate.

3.6 DRYING

The drying process simply removes the moisture absorbed by the gelatin during processing. Normal drying temperatue is 125°F ±5°F at a Relative Humidity below 80%.

3.7 MIXING THE SOLUTIONS

When mixing developer solutions, do not introduce excessive air into the solution because developer oxidize readily. Violent agitation weakens developer solution and forms taining compounds. Mixing should be gentle but thorough because the developer is heavier than water and the developer tends to remain at the bottom of the vessel. There are no precuations needed on the mixing of the fixing chemicals.

3.8 SHELF LIFE

Chemicals supplied by DatagraphiX are normally stable for a period of a year or more at the proper temperature. At 72°F (room temperature) DatagraphiX chemicals should be stable for about 18 months. Generally, for each 18°F change the shelf life will double or half depending upon the direction of change. e.g., A change from 72°F to 90°F will reduce the life to 9 months. The chemical should not be allowed to freeze. Silver film has a normal shelf life of two years in a controlled temperature - humidity environment.

Silver film has been certified in order to set standards for vehicles, sensitizers and emulsions. Depending upon the compounds of a given silver film, it is certified from the standards for a certain period of archival life, usually from 20 to 40 years.

3.9 SILVER FILM NOTES

- **Contrast** - The contrast of silver halide materials is extremely high in all instances.
- **Resolving Power** - High resolution is available in silver halide materials, however, because of grain, it is not as high as diazo materials.
- **Exposure Latitude** - A wide latitude of exposure is available with silver halides as compared to any other type photo-recording material.
- **Speed** - Silver halide films can be found in any speed range, but is at least 10^5 faster than the fastest diazo type materials.
- **Color sensitivity** - Silver halide films can be made sensitive to any color in the spectrum.
- **Keeping Qualities** - In controlled environment, unexposed silver halide film can be kept for at least two years.
- **Permanence** - Archival permanence can be achieved with silver halide film with proper development, washing and a controlled environment.
- **Suitability** - Silver halide film is suitable for any type photo-recording and duplicating.

SECTION IV

VESICULAR FILM

4.1 INTRODUCTION TO VESICULAR FILM PRINCIPLES

The vesicular film process is based on the use of diazonium compounds which are sensitive to ultraviolet light. When exposed to sufficient amounts of ultraviolet light in the 3400-4500 A° (Angstrom units) range the diazonium compounds decompose yielding nitrogen gas, water, and carbon dioxide.

4.1.1 BASIC VESICULAR COMPOSITION

Vesicular film is formed by bonding a thin emulsion of a heat sensitive resin containing diazonium salts onto a clear polyester plastic base film.

Figure 4.1 shows a simplified cross sectional view of an unexposed vesicular film showing the diazonium salts (compounds) suspended in an emulsion bonded to the base film.

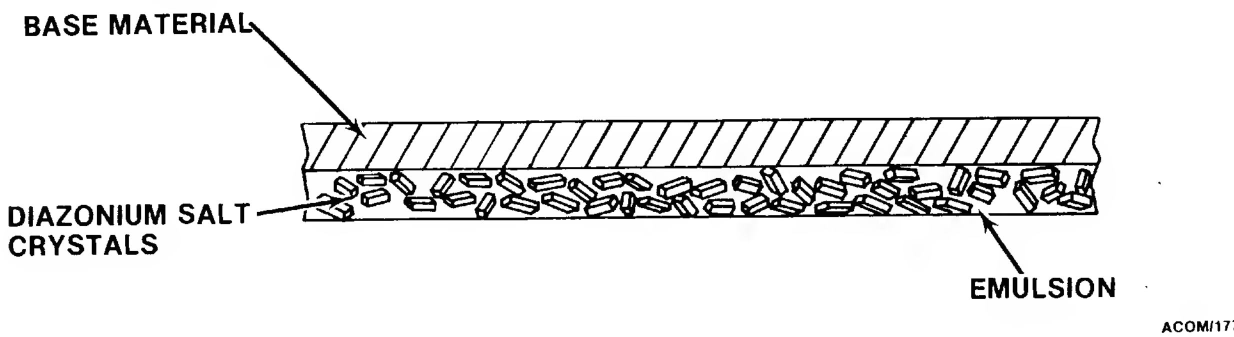


Figure 4.1. Unexposed Vesicular Film

To contrast, Figure 4.2 shows a simplified cross sectional view of a developed silver halide film image. The image is formed of microscopic metallic silver grains suspended in a gelatin emulsion and bonded to a plastic base film.

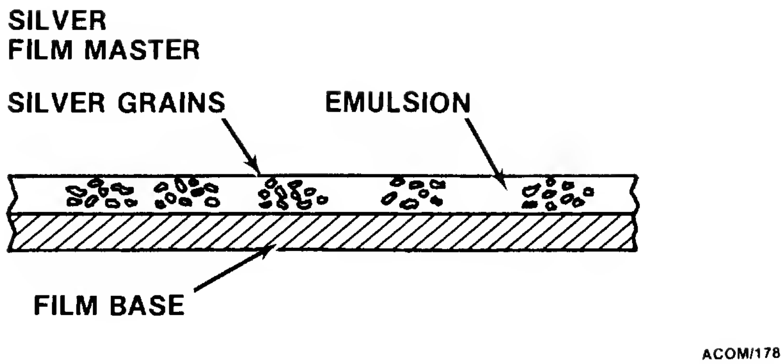


Figure 4.2. Developed Silver Film Master

4.1.2 BASIC VESICULAR COPYING

To duplicate a silver film image onto vesicular film, the first required action is to form an image within the copy (vesicular) film. This is done by making a contact print of the original. As shown in Figure 4.3, the silver film and copy (vesicular) film are placed emulsion to emulsion and held tightly together. The image is formed in the copy film by exposing the base side of the silver film to ultraviolet light.

The areas of metallic silver (in the emulsion of the master) block ultraviolet light and shield the copy film emulsion. The clear areas of the master film, however, have no metallic silver to block ultraviolet light so that the copy film emulsion is exposed in these areas.

The effect of ultraviolet light on the vesicular film is to cause diazonium compounds in the exposed areas to decompose into nitrogen gas, water, and carbon dioxide, forming minute pockets of high pressure within the emulsion. In the areas protected by the silver image, the diazonium compounds are unexposed to ultraviolet and still intact.

At this point, a latent image has been formed in the film, however, the image cannot be seen by the eye. Unless the copy film is developed shortly after exposure, the byproducts of diazonium decomposition seep out of the film and the image is lost.

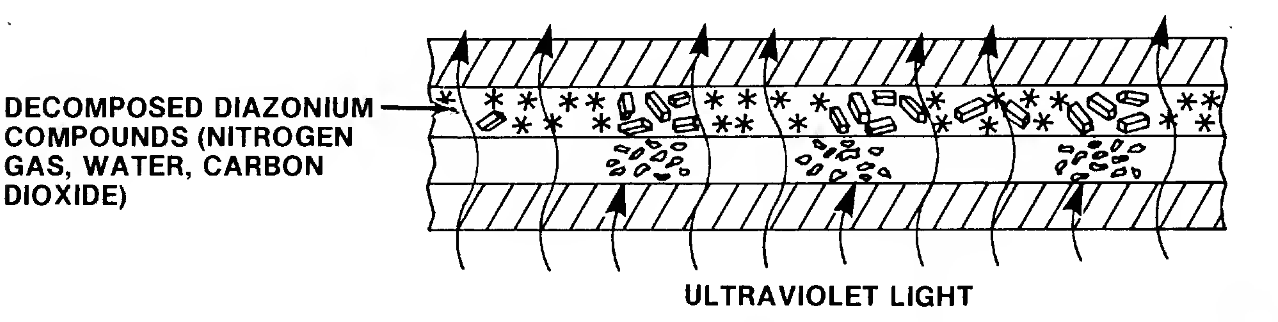


Figure 4.3. Exposure and Image Formation (Contact Print)

4.1.3 BASIC VESICULAR DEVELOPING

To develop vesicular film and capture the latent image formed during exposure, the film must be rapidly heated to the point at which the heat sensitive resin in the emulsion softens (approximately 265°F). At the same time, the heat causes the nitrogen gas released by diazonium decomposition to expand, the net result is the formation of bubbles or vesicles within the area of the emulsion which was exposed to ultraviolet light. This effect is illustrated in Figure 4.4, which shows that the diazonium compounds are still intact in the area which was not exposed to ultraviolet light.

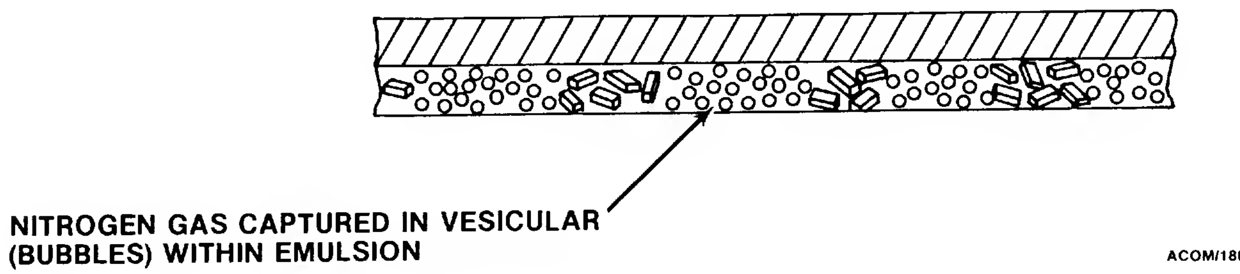


Figure 4.4. Vesicular Film Developing

The image has now been captured in the copy film in the form of extremely fine bubbles (vesicules) in the emulsion. These vesicules have the property of scattering transmitted light.

Viewing the developed copy by reflected light, the areas of bubbles appear light and the unexposed areas appear dark. Viewed by transmitted light, as in a microfilm viewer, the areas with vesicles block or scatter light which appear dark, and the areas without vesicles transmit light which appear clear.

4.1.4 BASIC VESICULAR IMAGE FIXING

After development, the image is usable. However, as shown in Figure 4.4, there is still residual diazonium material in the emulsion. If the film should, at any time, become exposed to ultraviolet light and sufficient heat (a condition common in most microfiche viewers) these remaining compounds can form vesicles and degrade the image.

To make the image permanent, the remaining diazonium compounds in the emulsion must be neutralized. This is done by first cooling the film to harden the emulsion and prevent further vesicle formation. The emulsion is then neutralized by exposing the film to intense ultraviolet light which decomposes all remaining diazonium compounds (see Figure 4.5).

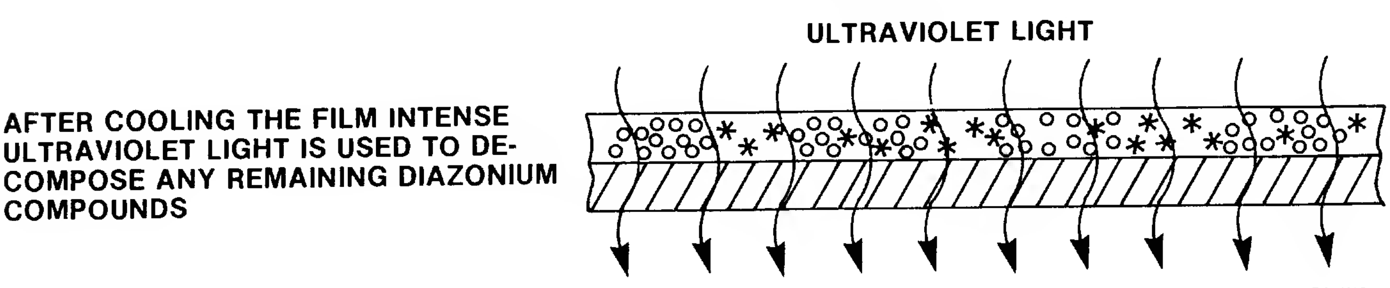


Figure 4.5. Vesicular Film Fixing

The gasses, formed by fixing, leak out of the film over a period of several hours, and the film should be allowed to cool (not subjected to heat for at least 1 hour), to render the image permanent.

4.1.5 FINISHED COPY FILM

After fixing and leaking out of gasses, the final permanent image is as shown in Figure 4.6. The vesicular image is now captured in a neutral emulsion that gives a durable working copy of the more delicate silver original.

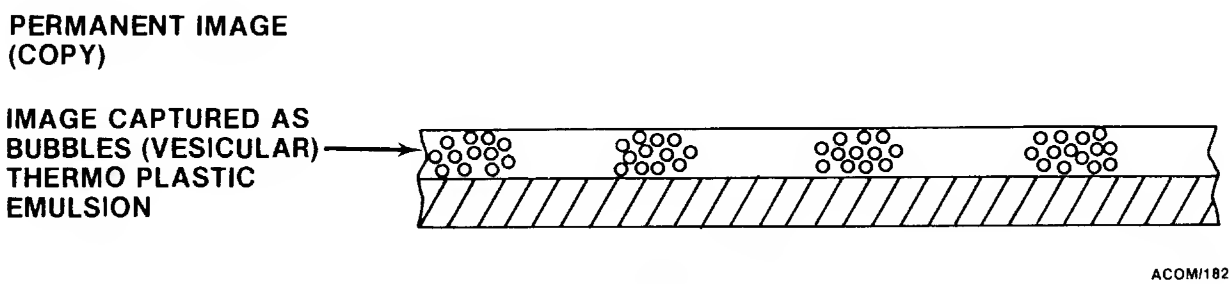


Figure 4.6. Finished Copy

4.2 DETAILED VESICULAR ANALYSIS

4.2.1 HISTORY

Although the basic principles of vesicular photography were discovered by Kalle in Germany in the nineteen-thirties, its commercialization did not begin until the fifties, the spin-off of a fruitful collaboration between a New Orleans businessman and a professor of physics at Tulane University. Instead of a printing plate which they had hoped to find, they developed a polymer-based film which they recognized as the foundation for a dry photographic system of potentially wide appliacation.

4.2.2 DETAILED COMPOSITION

Vesicular film consists of a thin layer of photosensitive emulsion coated onto a durable polyester base. The main ingredient is a thermoplastic hydrophobic resin, the use of which avoids the difficulties of the early vesicular films of Kalle, which were based on gelatin and found to be excessively moisture-and-humidity sensitive.

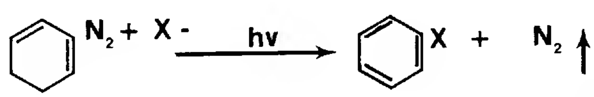
At room temperature and thereabouts, the hydrophobic resin is hard and stable. However, as is the case for all polymers, there is a temperature, called the glass transition temperature, Tg, above which the polymer softens and becomes subject to flow and consequent deformation. This property, the Tg of the vehicle, influences both the ease of creating a vesicular image and the subsequent temperature stability of that image.

Uniformly dispersed throughout the vehicle is a sensitizer. This is an aromatic diazonium salt of the same sort as is used in the diazo type process, although its photosensitivity to ultraviolet light is utilized in an entirely different manner here.

These two components, vehicle and sensitizer, are all that is required to form a vesicular image. Actual commercial films usually contain small amounts of various additives to optimize particular performance characteristics, but they do not influence the fundamental mechanism of image formation.

4.2.3 DETAILED VESICULAR COPYING

We are now ready to expose the film to ultraviolet light from about 350 to 400 nanometers in wavelength, such as is supplied by mercury arc lamps, xenon/mercury lamps, or blacklight-blue fluorescent tubes. Upon exposure, the diazonium salt is decomposed, and one of the products of its photolysis is nitrogen gas (Figure 4.7). This gas is temporarily trapped within the polymer vehicle, and pressure pockets within the emulsion are formed such that local pressure increases threefold.



ACOM/183

Figure 4.7. Photochemical Decomposition of Sensitizer

4.2.4 DEVELOPING IN DETAIL

The gas molecules responsible for this pressure constitute the latent image in vesicular photography. While the pressure is insufficient to deform the vehicle at room temperature and eventually dissipates as the nitrogen slowly diffuses from the film into the atmosphere, if we quickly apply heat to the film, the combination of softened plastic and increased gas pressure results in the formation of tiny bubbles, or vesicles, in the layer. Any form of heat sufficient to raise the emulsion temperature shows Tg is sufficient (typically 240 - 300°F for ¼ to ½ second).

4.2.5 FIXING

Upon removal of the heat, the vehicle hardens once again, and a permanent bubble image has been created. All that remains is to fix the image by administering an overall ultraviolet exposure sufficient to destroy all remaining sensitizer. If the film is not subjected to heat following this fixing exposure within a few hours, the gas diffuses from the layer and the film is no longer light-sensitive.

4.2.6 FINISHED COPY FILM

The imaged layer thus has a honeycomb-like structure of bubbles, 1-5 microns in size, surounded by

a thermoplastic matrix. These vesicles contain air, and thus have an index of refraction different from that of the surrounding polymer. As a result, light impinging on the film is scattered by a combination of reflection and refraction processes, and useful photographic density is obtained.

This property, the production of photographic density by light scattering, is a fundamental departure from conventional photography and is unique to the vesicular process (Figure 4.8). Conventional photographic images, whether they consist of silver grains or the azo dye molecules of the diazo type process, attenuate light by absorbing it. The vesicles, in contrast, scatter the light out of the observer's view with very little absorption. This basic fact leads to several unique properties of vesicular images.

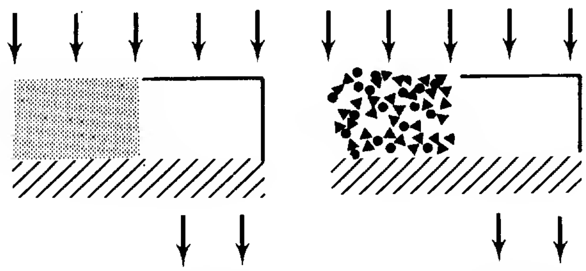


Figure 4.8. Light Absorption vs. Light Scattering

Graduations in density are governed by the number and distribution of vesicles in the layer. Figure 4.9 represents a cross-section of a step-wedge printed on vesicular film. The deeper the expousre has penetrated into the layer, the more vesicles are created and the greater their scattering power. Since vesicles are produced in areas corresponding to clear areas of the original, the vesicular image is of opposite photographic sign and the process is negative-working. As with nearly all photographic processes, density is a direct function of log exposure, which is in turn, determined by the exposure time, the intensity and spectral output of the source, and the distance of the film from that source.

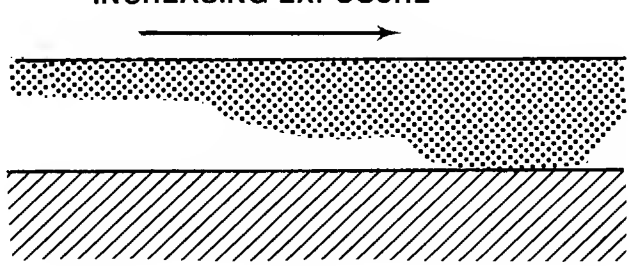


Figure 4.9. Cross-Sectional View of a Vesicular Stepwedge

4.3 VESICULAR FILM ADVANTAGES

The advantages of vesicular photography are considerable. Dry rapid processing by light and heat alone; no need for darkroom facilities because of film's ultraviolet sensitivity allows handling in ordinary room light; no chemicals to mix or maintain; tough permanent images of a physical rather than chemical nature; no chemical effluents to dispose of; and no use of expensive silver, which also means no need for silver recovery systems.

No liquids of any sort are involved in the dry vesicular process; no chemicals are required for developing and fixing the image; no highly-skilled darkroom personnel are needed to operate the equipment; and there is no waiting for films to be processed before they can be viewed. Heat development immediately follows exposure in a single operation, and the image is ready for use. There is also no need for storage and handling of ammonia or other potentially hazardous chemicals; thus total environmental compatibility, a factor which becomes increasingly important as time goes on, is maintained.

SECTION V

COMPUTERS

5.1 SYMBOL USAGE

To understand the language of computers, you first need an understanding of symbol usage and then a working knowledge of binary logic.

A symbol can convey information or meaning; however, the symbol may mean one thing to some and something else to others, and have no meaning at all to still others who do not know the symbol. Thus, a symbol conveys information only if it is recognized and understood.

A symbol itself is not information. A symbol merely represents information. The printer characters on this page are symbols, and when understood, they convey a meaning. To all who cannot read English, the symbols are meaningless.

Presenting data to a computer system is similar to communicating with someone by the written word. Information to be conveyed is reduced to a set of symbols that the computer can use and understand. Since computers run by electricity and electric current is either on or off, a number system that can easily represent on and off is needed. The binary number system uses just the numerals 0 and 1 (1 for on, 0 for off). Computers use binary numbers, in one way or another, in everything they do.

5.2 THE DECIMAL AND BINARY SYSTEMS

The decimal system is known as the base-10 number system. It has 10 different symbols that make up all numbers in the system (1, 2, 3, 4, 5, 6, 7, 8, 9, 0). Also, the place values are found by multiplying 10 by itself over and over, giving the 10s place, the 100s place, the 1000s place, and so on. Each place value is found by multiplying the next lower place value by 10, not by itself. The place values can thus be represented as "powers" of the base, meaning the number of times the base is multiplied by itself:

$$\begin{array}{rll}
10{,}000 = & 10 \times 10 \times 10 \times 10 & = 10^4 \\
1{,}000 = & 10 \times 10 \times 10 & = 10^3 \\
100 = & 10 \times 10 & = 10^2 \\
10 = & 10 & = 10^1 \\
1 = & & = 10^0
\end{array}$$

Figure 5.1. Place Values of the Decimal System

Now that we have given some characteristics of the base-10 system, let's describe the binary, or base-2 system. The binary system has two different symbols that make up all the numbers in the system. The two symbols are, of course, 0 and 1. The place values are found by multipling 2 by itself over and over, giving the 2s place, the 4s place, the 8s place, 16s, 32s, 64s, and so on. Notice that each place value is found by multiplying the next lower value by 2, not by itself. So after the 128s place comes the 256s place, not some value obtained by multiplying 128 by 128. The rightmost position (in any numbering system) is the units place. The place values can thus be represented as powers of the base:

$$
\begin{aligned}
256 &= 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 &&= 2^8 \\
128 &= 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 &&= 2^7 \\
64 &= 2 \times 2 \times 2 \times 2 \times 2 \times 2 &&= 2^6 \\
32 &= 2 \times 2 \times 2 \times 2 \times 2 &&= 2^5 \\
16 &= 2 \times 2 \times 2 \times 2 &&= 2^4 \\
8 &= 2 \times 2 \times 2 &&= 2^3 \\
4 &= 2 \times 2 &&= 2^2 \\
2 &= 2 &&= 2^1 \\
1 &= &&= 2^0
\end{aligned}
$$

Figure 5.2. Place Values of the Binary System

So the binary number 110101 stands for:

$(1 \times 2^5) + (1 \times 2^4) + (0 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$ or

$$
\begin{aligned}
1 \times 2^5 &= 32 \\
1 \times 2^4 &= 16 \\
0 \times 2^3 &= 0 \\
1 \times 2^2 &= 4 \\
0 \times 2^1 &= 0 \\
1 \times 2^0 &= \underline{1} \\
& 53
\end{aligned}
$$

In the exercise above, numbers were converted from the binary to the decimal system. Converting a number from one system to another means that you change the way the number is written but do not change its numerical value. The table below shows the binary equivalent of the decimal numbers from 0 to 15.

Binary	Decimal
0	0
1	1
10	2
11	3
100	4
101	5
110	6
111	7
1000	8
1001	9
1010	10
1011	11
1100	12
1101	13
1110	14
1111	15

Figure 5.3. Binary Equivalent of the Decimal Numbers

Information can be transmitted to the computer from many input/output (I/O) media including punched cards, paper tape, magnetic tapes, magnetic disks, magnetic ink characters, optical characters, and CRT terminals.

A computer **input** device is designed to read information from one of the input media. The incoming information is then converted to binary code and sent to the computer for processing or storage.

A computer **output** device receives information from the computer and stores that information again on punched cards, paper tape, magnetic tapes or disks, printed forms, microfilm, etc.

5.3 THE OCTAL AND HEXADECIMAL SYSTEMS

Binary numbers are excellent for computers to use and difficult for humans to use. The main difficulty in practice is that binary numbers are usually so long that errors occur if humans try to write, read, or pronounce them. Fortunately, there are two number systems that humans can use as shorthand ways of reading, writing and saying binary numbers. They are the octal number system and the hexadecimal number system. While these two number systems are full-fledged, distinct number systems in their own right, they would be of no interest to us if they were not related to the binary system in a very useful way. Most computers are designed to make it easy for humans to use one or another of these shorthand system, but not both. In any case, the computer itself always uses the binary system; the shorthand systems are only for the convenience of humans.

5.3.1 THE OCTAL NUMBER SYSTEM

The octal system is based on 8. It has eight different symbols (0 thru 7), and the place values are power of 8, namely units, 8s, 64s, 512s, and so on. The octal number 5013 stands for $(5 \times 8^3) + (0 \times 8^2) + (0 \times 8^1) + (3 \times 8^0)$ or,

$$\begin{aligned}
5 \times 8^3 &= 5 \times 512 = 2560 \\
0 \times 8^2 &= 0 \times 64 = 0 \\
1 \times 8^1 &= 1 \times 8 = 8 \\
3 \times 8^0 &= 3 \times 1 = \underline{3} \\
& \qquad\qquad\quad 2571_{10}
\end{aligned}$$

You can see that converting an octal number to decimcal is just like converting a binary number to decimal, except that you use powers of 8 rather than powers of 2. Now that we've had a brief look at octal as a number system, let's see how it can be used as a shorthand for the binary system.

The first eight octal numbers and the binary equivalent are shown below:

Octal	Binary
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111

The highest number that can be written with a single digit in octal is 7, and to write 7 in binary numbers requires three binary digits. Each octal digit can be written using three binary digits, as shown below:

Octal	Binary
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Figure 5.4. Octal and Binary Equivalents

In any binary number, no matter how long, three binary digits can be written in octal shorthand as a single octal digit. For example, the binary number 110101011 can be written as 653_8. Notice that every three binary digits is written as the octal equivalent, and how much easier it is to read and say the octal form of the number than the binary.

5.3.2 THE HEXADECIMAL NUMBER SYSTEM

The hexadecimal number system is based on 16. The name is derived from the Greek word for six and the Latin word for ten. This system has sixteen different symbols (0 thru 9 plus A, B, C, D, E & F). The A thru F stand for 10 thru 15, respectively. The following table shows the first 17 numbers in four systems:

Decimal	Binary	Octal	Hexadecimal
0	0000	0	0
1	0001	1	1
2	0010	2	2
3	0011	3	3
4	0100	4	4
5	0101	5	5
6	0110	6	6
7	0111	7	7
8	1000	10	8
9	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F
16	10000	20	10

Figure 5.5. Comparing the Decimal, Binary, Octal and Hexadecimal Systems

The place values in the hexadecimal system are units, 16s, 256s, 4096s, and so on. The hexadecimal number 243 is equivalent to: $(2 \times 16^2) + (4 \times 16^1) + (3 \times 16^0)$ or

$$\begin{aligned}
2 \times 16^2 &= 2 \times 256 = 512 \\
4 \times 16^1 &= 4 \times 16 = 64 \\
3 \times 16^0 &= 3 \times 1 = \underline{3} \\
& \qquad\qquad\quad 579_{10}
\end{aligned}$$

As with the octal system, the importance of the hexadecimal system is in its use as a shorthand for binary numbers. This time, however, we need four binary digits for each hexadecimal digit. So, the binary number 10001001 is 89_{16} and the binary number 11001001 is $C9_{16}$. Binary digits are marked off in groups of four starting from the right side of the number.

The following chart is an example of a character code set in both octal and hexadecimal.

CHARACTER	OCTAL	HEXADECIMAL
1	1 000 001	F1 1111 0001
2	2 000 010	F2 1111 0010
3	3 000 011	F3 1111 0011
4	4 000 100	F4 1111 0100
5	5 000 101	F5 1111 0101
6	6 000 110	F6 1111 0110
7	7 000 111	F7 1111 0111
8	10 001 000	F8 1111 1000
9	11 001 001	F9 1111 1001
0	12 001 010	F0 1111 0000
A	61 110 001	C1 1100 0001
B	62 110 010	C2 1100 0010
C	63 110 001	C3 1100 0011
D	64 110 100	C4 1100 0100
E	65 110 101	C5 1100 0101
F	66 110 110	C6 1100 0110
G	67 110 111	C7 1100 0111
H	70 111 000	C8 1100 1000
I	71 111 001	C9 1100 1001
J	41 100 001	D1 1101 0001
K	42 100 010	D2 1101 0010
L	43 100 011	D3 1101 0011
M	44 100 100	D4 1101 0100
N	45 100 101	D5 1101 0101
O	46 100 110	D6 1101 0110
P	47 100 111	D7 1101 0111
Q	50 101 000	D8 1101 1000
R	51 101 001	D9 1101 1001
S	22 010 010	E2 1110 0010
T	23 010 011	E3 1110 0011
U	24 010 100	E4 1110 0100
V	25 010 101	E5 1110 0101
W	26 010 110	E6 1110 0110
X	27 010 111	E7 1110 0111
Y	30 011 000	E8 1110 1000
Z	31 011 001	E9 1110 1001

Figure 5.6. Octal and Hexadecimal Representation of Characters

5.4 COMPUTER VOCABULARY

Bit:	Abbreviation for binary digit, a single unit of information. A bistable device (Flip Flop) that can represent one of two possible states. (A "set" or "one" condition or a "clear" or "zero" condition.)
Byte:	A grouping of six or eight bits that represent a unique alpha-numeric character.
Word:	A grouping of a known quantity of bits. The word could be composed of all bits set to one's or cleared to zero's or any configuration of both states.
Register:	A display of the state of the bits in a group. Usually indicated by lights. A light turned on, in that bit position represents that bit as a "one". The light off condition represents a "zero". A computer word would be displayed in a register.
Sign Bit:	Sometimes called the most significant bit (**MSB**). The left most bit in a register. If the word is a product to be used in an arithmetic operation, then the **MSB** is considered to be the sign bit. If the sign bit is zero, the number following it is a positive quantity. If the sign bit is set, the number is a negative quantity.
Register Modulus:	The maximum number of bits a register could contain, minus the sign bit. A 30 bit arithmetic register would have a modulus of 29.
Overflow/End Off:	The loss of the most significant bit of a register, caused by an operation that exceeds the register modulus.
Carry:	Assume that a 16 bit register was set to all ones. A bit added to the least significant bit of the register could not be absorbed due to the face that the bit in that position is already set. The **LSB** would then pass the incoming bit on to the next highest order bit. This carry would continue to be passed up the line. When the most significant bit was reached, it would pass the incoming bit on, causing an overflow condition, as no higher order stage existed after the **MSB**.
Accumulator:	Adder, or sum network a register where all arithmetic operations are performed in the computer (add, subtract, multiply, divide) the bits in the adder would absorb or generate carries, depending on their current state.
Shift Register:	A register where a group of bits can be shifted left or right a specified number of positions. A left shift of one, would take the **LSB** and move it on to the next highest order stage. The **MSB** could be dropped off the end (overflow) or "end around" into the **LSB** position. This operation would depend on the type of shift called for.

Op Code: Also instruction word, function word or command. A unique configuration of bits that instructs the computer to perform a specified operation. E.g., A 0010 would tell the computer to place a data word in the "A" register. The function or op code would be placed in the function register, and translated by the computer circuits. Also, a command to another piece of equipment, telling it to start or stop an operation.

Instruction Repertiore: A list of computer op codes, generally in numerical order. e.g., 00 = Stop computation; 01 = Load the A register; 02 = Test if A register is positive.

Instruction Mneumonics: The abbreviated name of each computer instruction. E.g., A function code of 01, "load the A register" would be known as **LDA**. The "test if 'A' is a positive number", would be known as **SPL**.

Program: A group of instruction words that inform the computer how, and in what sequence, it should perform operations on "raw" (unprocessed) data.

LOCATION	PROGRAM			COMMENTS
00000	LDA	●	Lettuce	Load a with lettuce
00001	CAS	●	Salad	Compare if A = salad
00002	JP	●	Toss	
00003	ADD	●	Celery	No, add celery to A
00004	CAS	●	Salad	Compare if A = Salad
00005	JP	●	Salt & Pepper	Yes, go to seasoning
00006	ADD	●	Tomato	No, add tomato
00007	SUB	●	Onions	Take away onions
00010	JP	●	Toss	Go to toss
00011	STA	●	Bowl	Store A at bowl

Branch: A point in a program, where the computer must decide which path it should follow in its computation. The computer might be asked to test if the A register contains a negative number. If it does, the computer is then instructed to branch away from program number 1 and start executing program number 2.

Software: The name applied to any operating program used by the computer (hardware).

Flowcharting: The process of laying out on paper, the logical sequence of operations in a program.

Operand: The data word referenced by the computer instruction, e.g., LDA -1057. This instruction will place the number 1057 in the A register. In this case, the operand is the number 1057.

Complement: The binary complement of a number is the opposite of the original number. A binary one complemented (inverted) is a binary zero. A binary zero becmes a binary one. (1101 = 0010)

Core memory: The device used by a computer to store or retain information, such as a program. Composed of arrays of magnetic material. The core can be switched to, and retain, either binary state. (One or zero).

Address/Location: A 16 bit computer would contain a core memory, made up of many groups of 16 cores each. Each 16 core group would have a unique number assigned to it. Group 1 will then be called address zero (00000), group 2 would be address one (00001), etc. A memory that contained 8,192 sixteen bit locations would go up to address 17,777.

Sector: A core memory could be divided up into equal divisions. A small memory of 4,096 address could be physicall divided into 8 smaller sections of 512 addresses each. The first 512 addresses would be accessed as sector zero, the next 512 would be designated sector one, etc.

Main Frame: Central processor or computer.

Peripheral Device: Any external device that communicates with the computer. The peripheral equipment can send data to the computer (card reader), receive data from the computer (as a paper tape punch) or both (such as magnetic tape).

Interface: The device that allows communication between the main frame and peripheral devices. Any circuit that makes one form of logic compatible with any other type of logic. The "tape control unit" is the interface between the magnetic tape unit and the central processor.

Interrupt: An "attention getting" signal to the processor. A signal from a peripheral device denoting the completion of an operation.

An internally generated signal, telling the processor that it is experiencing a power failure.

Status Word: A bit encoded word sent to the computer by a peripheral device at the end of its requested operation. Each bit by being set (marked) signifies that a specific situation has occurred. e.g., Bit 16 - 1 denotes data errors, bit 10 = 1 denotes a data overflow occurred.

Buffer: A storage device where data is read into, or out of, when communicating with peripheral equipment. The computer reads data from core memory and buffers it out to magnetic tape.

Bootstrap: A key in loader. A hard wired program, stored in dedicated addresses. It is initiated, to load in other programs via peripheral equipment.

Debug: The process where a programmer must locate program errors and make corrections or additions to get the program running properly.

Parity: A count of all data bits set. The parity of a data word can be odd or even. If odd parity is assigned, then the data bits are counted. If an even count is detected, an additional non-data bit called the parity bit is set. This makes the overall data count, odd. The parity operation is used for testing data loss, and can be a function of hardware or software.

Diagnostic Test: A maintenance program that can isolate a malfunction, and narrow the faulty circuit down to one of two possible choices. A standard maintenance test can only define a problem within a board area.

Checksum: A program, that upon loading data into core, adds the data up, and obtains the sume of all the words. This checksum is then compared against a checksum word located at the end of the data loaded into core. If the two checksums are not equal, a bad "load in" operation has occurred and the operator is so advised.

Assembler: A program that accepts a mneumonic coded input program, and translates the mneumonic codes into machine language (binary format).

Sub-Routines: A smaller program, located within a larger executive program. The sub-routine will be executed many times on command from the master program. The usefulness of a subroutine is that it can be called on at any time, from any place in the exec. When the sub-routine has finished its operation, it returns control back to the exec.

Image: A duplication of data, stored on another medium. A "core image magnetic tape dump" routine takes the data exactly as it finds it in core, and writes it out on magnetic tape.

Page: A chassis of a computer, that contains all of the logic associated with one form of its operation. e.g., a general purpose (GP) computer could containa core memory page, an input, output (I/O) page, a control logic page and an arithmetic page.

Master Clock: All operations within a computer must be controlled so that they do not clash with each other. This operation is called "timing" and is used throughout the main frame. The timing generator could be a crystal controlled oscillator, or a timing chain made up of Flip Flops and delay lines.

SECTION VI

FLOWCHARTING TECHNIQUES

6.1 INTRODUCTION TO FLOWCHARTING

A flowchart is a graphic representation of a process or sequence of events, and is commonly used in computer program design. There are many symbols which are used in flowcharting, however, we will use 5 basic symbols that can describe nearly any process (Figure 6.1).

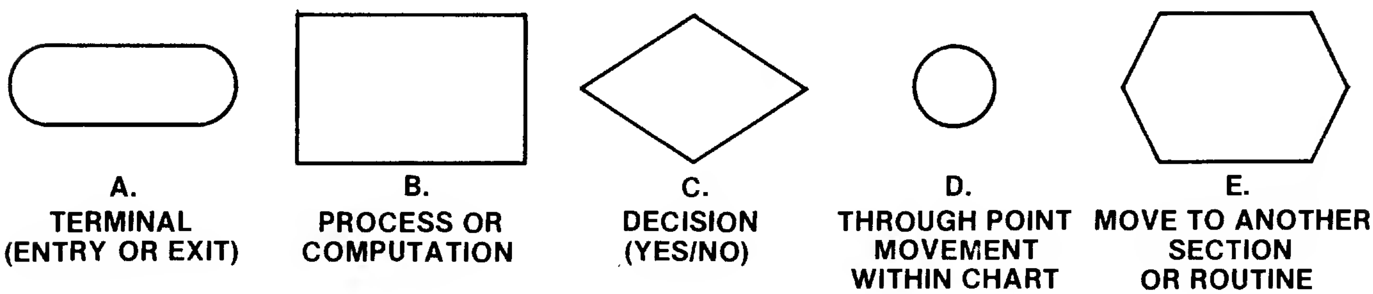


Figure 6.1. Flowcharting Symbols

The first symbol, (A) is used to designate the start or end of a process that is a point of entry or exit. The second symbol (B) represents a processor computation - that is, some action or manipulation. The next symbol (C) represents a decision often based on the previous operation. The decision must be a yes/no decision and the symbol will have two exits for separate actions. The next symbol (D) is used to indicate that the flow chart moves to another point on the page identified with the same symbol. The last symbol (E) is often used in the same manner as the process or computation symbol. The difference being that the process has several steps and is a completely separate flowchart, or as it is often termed, a subroutine. At the completion of the subroutine, the last action designated will be "return", meaning that the flow now goes back to the symbol from which it came. Additional symbols and meanings may be found in flowcharts for computer programs or more complex processing manipulations, however, the five described are the ones most likely to be found in DatagraphiX documentation.

A sample flowchart demonstrates how these symbols are used. The example consists of a simplified flowchart for making coffee in a drip coffeemaker (Figure 6.2), with a subroutine flowchart (Figure 6.3). Remember the significance of each of the symbols discussed and follow the charts. The "Is Coffeepot Empty?" is a decision box. If the pot is not empty, obviously we cannot make more coffee in it. "Fill empty pot with water" requires an action or process. In the computer, we may tell it to compute the square root of a particular number in this box. "Put coffee grounds in basket" is another action or process, but it requires more than one step. If these steps are used more than once or may

be used in several different programs, we make up the "subroutine" flowchart. Then when we run across the need for that subroutine in a flowchart we are writing, we just call it up by a code name. After the subroutine is completed, we return to the same place in the flowchart that called for the subroutine. The decision box "Is water indicator light on?" would put the computer into a "loop" situation if the light was not on. It would sit and ask the question until the answer was yes. If we didn't want the computer to continue in this "loop" indefinitely, we would add a box to tell it to check for the light only a certain number of times and if the light was still off, to stop. The small circle with the "A" indicates that the flowchart continues at another place on the page.

FLOWCHART FOR MAKING A POT OF COFFEE

IN A DRIP COFFEE MAKER

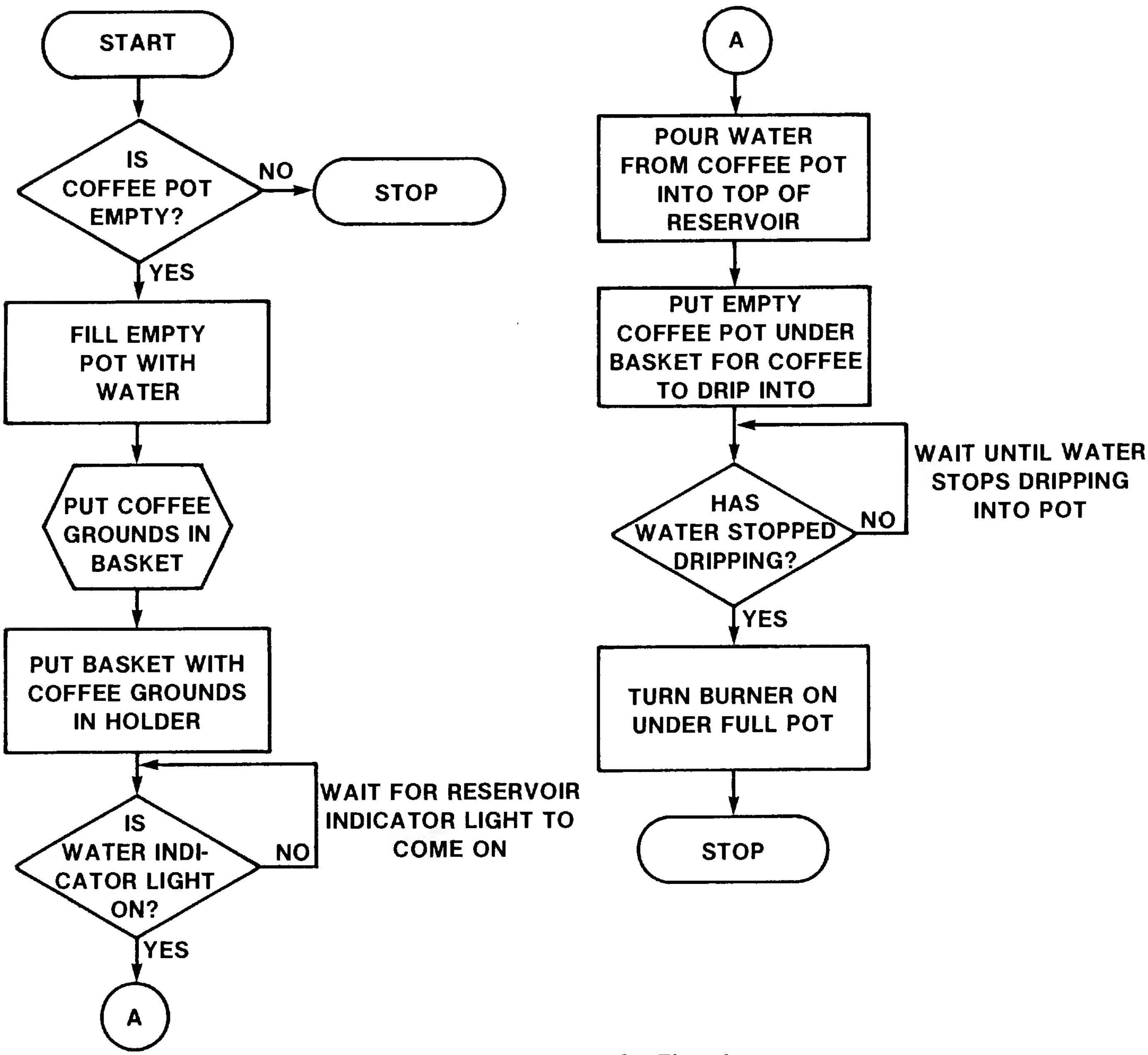


Figure 6.2. Example of a Flowchart

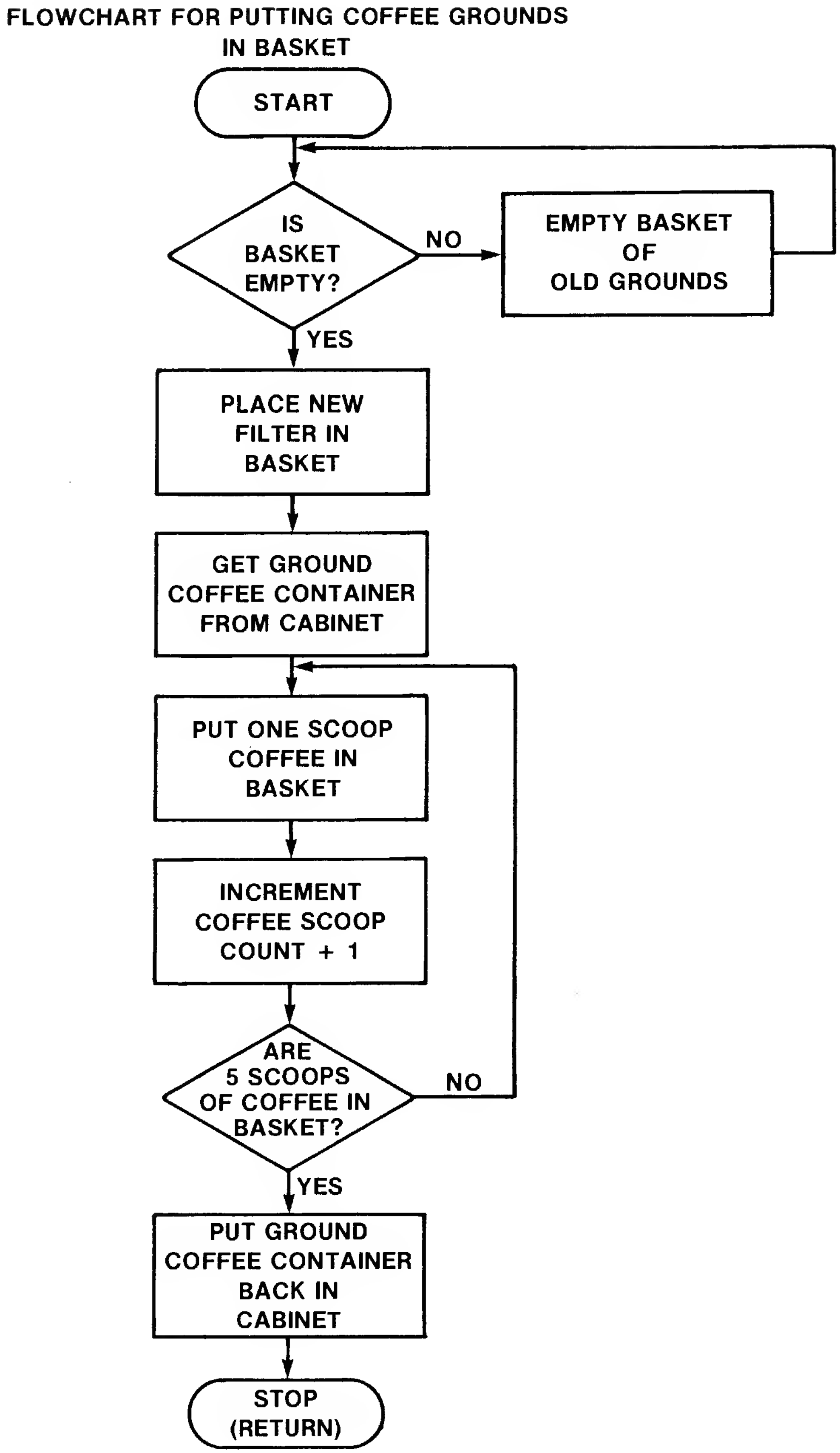


Figure 6.3. Subroutine

SECTION VII

DIGITAL LOGIC BASICS

7.1 INTRODUCTION

Unlike analog devices, where signals may vary over a wide range, digital or binary logic devices deal essentially with only two conditions. The two states are either "on" or "off". Simple digital logic systems or devices can be easily demonstrated using switches. Two common logic functions are the "and" and the "or" function.

The "and" function may be simply demonstrated as shown in Figure 7.1. The lamp will only light if both switches are closed. When speaking of digital devices, a common convention is the use of a "truth-table" to describe the function of the device. For simplicity sake, let us assume a common convention, that a closed switch is a digital or binary "1" or "on", and that an open switch is a binary or digital "0" or "off". As is also common, lets assume that the lamp is the output of the device and that if power is applied to the lamp, the output is a binary "1", and if power is not applied, the output is a binary "0". Since each variable (switch) is a two state device (either on or off), it will require a four entry table to describe all possible conditions.

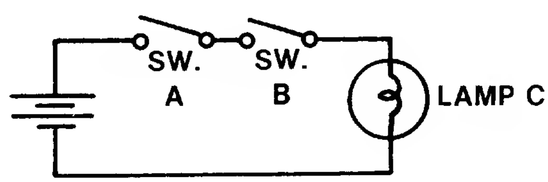


Figure 7.1. The "And" Function

Switch A	Switch B	Output C
0	0	0
1	0	0
0	1	0
1	1	1

Figure 7.2. "And" Truth Table

The table thus constructed (Figure 7.2) describes the function of the circuit. Note that the only condition which will cause the output to go "true" (that is to a "1" state), which will light the lamp is when both switches are closed. That is, both "A" and "B" must be "true" or "1s" in order to make the term "C" true and apply power to the lamp. The symbol which is commonly used to represent the logic function which was just described is shown in Figure 7.3. The figure represents an "and" function, both inputs must be true for the output to be true.

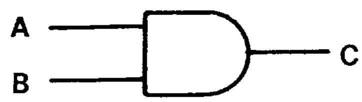


Figure 7.3. "And" Function

Another common logic function is the "or". This can also be demonstrated using switches as in Figure 7.4. It can be easily seen that either switch being closed will apply power to the lamp. A "truth-table" for the device is shown in Figure 7.5 and the symbol used to represent the "or" function is shown in Figure 7.6. Either input being "true" will cause the output to be "true".

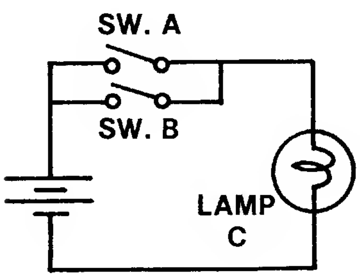
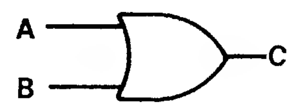


Figure 7.4.
"Or" Function

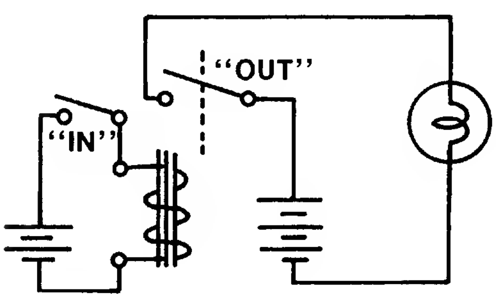
Switch A	Switch B	Output C
0	0	0
1	0	1
0	1	1
1	1	1

Figure 7.5. "Or" Truth Table



"Or" Symbol
Figure 7.6.

Another common logic device is the "buffer". This function can be demonstrated using a relay which allows a small amount of power on the coil to control a large amount of power on the contacts. A simple circuit, a truth-table and symbol representing the buffer are shown in Figure 7.7.



IN	OUT
0	0
1	1

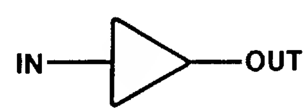
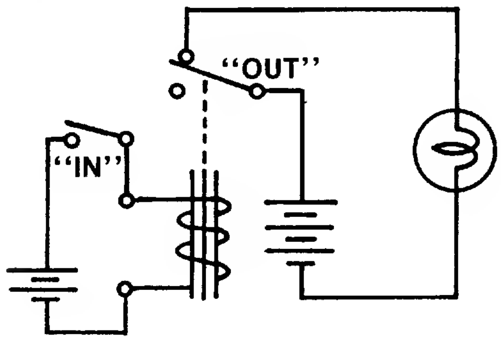


Figure 7.7. Buffer Function, Truth Table and Symbol

Another common logic function is the inverting buffer. This can also be demonstrated using a relay. Note that, in this case, the output is the opposite of the input, if input is "1", the output is "0". The circuit, truth-table and symbols used to represent the inverting function are shown in Figure 7.8. Note that the "bubble" shows as either the input or output of a symbol designates an inversion (or inverting function).



IN	OUT
0	1
1	0

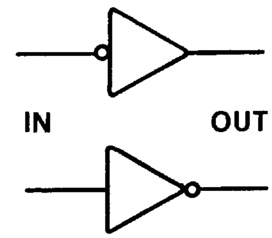
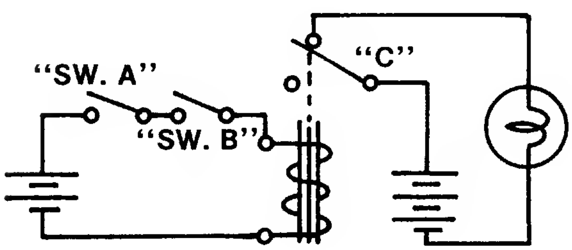


Figure 7.8. Inverter Function, Truth Table and Symbol

When two of the concepts previously discussed, the "and" and an "inverting buffer" are combined, a new function is created - the "nand". Remember that the "bubble" on the output indicates inverstion. The circuit, truth-table and symbol are shown in Figure 7.9. Note that, in this case, the only state which makes the output false is when both inputs are "true".



Switch A	Switch B	Output C
0	0	1
1	0	1
0	1	1
1	1	0

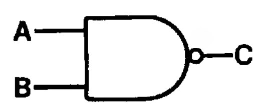
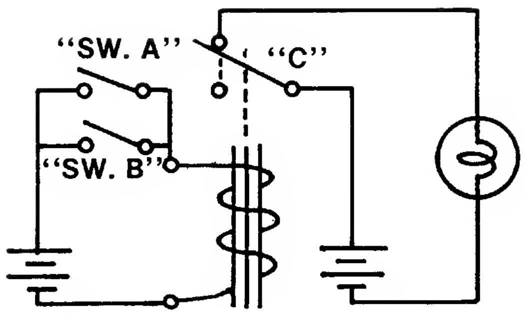


Figure 7.9. "Nand" Function, Truth Table and Symbol

Combining the concepts of the "or" and the "inverting buffer" allows creation of another common device, the "nore". In this case, either input being "true" will cause the output to go "false". Only if both inputs are "false" will the output be "true". The circuit, truth-table, and symbol are shown in Figure 7.10.



Switch A	Switch B	Output C
0	0	1
1	0	0
0	1	0
1	1	0

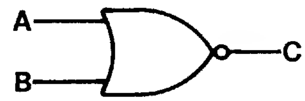
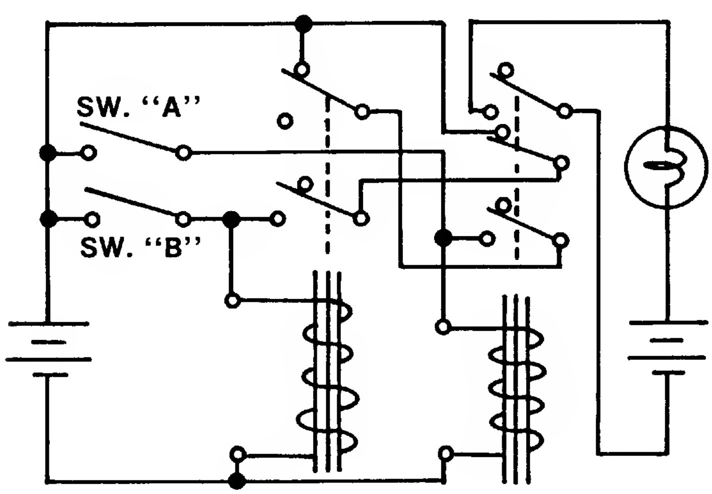


Figure 7.10. "Nor" Function, Truth Table and Symbol

Another frequently used digital device, again a combination of previously discussed devices is usually used as a data storage device or memory. This is the "latch". In this case, the example is one constructed of a pair of cross coupled "nor" gates. The difference in this case, is that switches "A" and "B" may be momentary contact switches because the device will remember what has been done to the inputs. A pulse on Switch "A" will set the latch so that the output is "true". A pulse on Switch "B" will reset the latch so the output is "false". The circuit, truth-table and symbol representation are shown in Figure 7.11. Note that if both switches are pushed at the same time, the output will be indeterminate and, in fact, may come up as either true or false. In a logic circuit, this would be an illegal condition and as such, should be avoided.



Switch A	Switch B	Output C
0	0	x
1	0	0
0	1	1
1	1	x

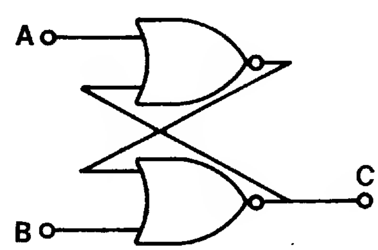
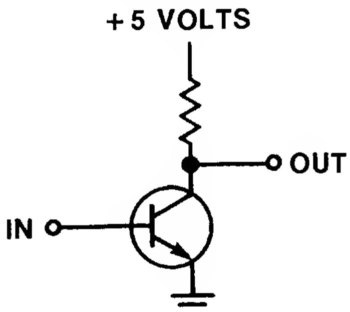


Figure 7.11. "Nor" R. S. Latch, Truth Table and Symbol

While digital devices can be and are built utilizing switches and relays as just demonstrated, the result is usually combersome, slow, and wasteful of power. To save space and energy and increase speed, logic is now built using transistors. About the simplest device to convert to transistors from our previous discussion, is the inverter. To convert, we must first assume several conventions which will apply to "TTL" (**Transistor-Transistor Logic**) as the group of devices which will be discussed are called. First we must assume that a high logic level is +2.4 volts or more up to +5 volts. A low logic level is 0.0 volts or ground. We will further assume, for this example, that a logic high level is a "true" or logical "1" and that a low is a "false" or logical "0". The circuit, truth-table and symbol are shown in Figure 7.12. The presence of ground or logic "0" on the base of the NPN transistor, turns off any conduction by the transistor, thus the output is looking at +5 volts through the pull up resistor. A logical "1" or +2.4 volts on the base of the transistor turns it on to saturation. The output in this case is looking essentially at 0 volts or ground. There is actually a few tenths of a volt drop across the transistor but for practical purposes, the output is ground. It is obvious that, used in this manner, the transistor is functioning as a switch either turned all the way on, or all the way off.



IN	OUT
0	1
1	0

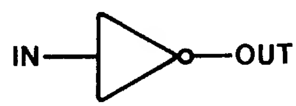


Figure 7.12. Simple Inverter Buffer, Truth Table and Symbol

A more complicated design, and one more suited to logic uses, is two-output "nand" gate. Everything in the circuit is conventional except for the transistor Q1 (Figure 7.13). Unlike most transistors, Q1 has two emitter junctions. This feature allows Q1 to be turned on by grounding either of the emitters. In other words, it is necessary to back bias both emitter-base junctions to keep Q1 from conducting. If Q1 is turned off, Q2 is turned on by the base-collector current of Q1. Q2 being turned on pulls the potential on the base of Q3 lower than that of its emitter, turning off Q3. Q2 also pulls the potential on the base of Q4 above that of its emitter. This turns Q4 "hard" on thus, if both inputs A + B are high levels or logic "I"s, the output will be ground or logic "0". If either or both of the emitters of Q1 is/are at ground potential, the emitter-base junction draws current, turning on Q1. This back biases the base of Q2, which shuts off Q2. Shut off of Q2 allows the base of Q3 to be pulled up towards +5 volts, turning on Q3. The base of Q4 is allowed to ground through the 1K resistor and turns off, thus the output goes toward +5 volts. The truth-table and symbol for this gate are shown in Figure 7.14. The circuit shown is one of the four such gates in a standard 7400 TTL chip package.

Another common TTL Logic device is the "nor" function shown schematically in Figure 7.15. In this case, the "or'ing" function is performed by transistors Q3 and Q4 which are connected in parallel. If the emitter of Q1 (the A input) is held high, Q1s base to collector current will turn on Q3. With Q3 conducting, Q5 is turned on and Q6 is turned off, thus the output will be low. A high on input B will have the same effect through Q2 and Q4, only if both inputs are grounded. Turning on both Q1 and Q2, both Q3 and Q4 will be turned off allowing the base of Q6 to be pulled high and the base of Q5 to go to ground through the resistors. Only in this case will the output go high. The truth-table for this

device and its logic symbol are shown in Figure 7.16. This circuit is typical of the "nor" gates as found in the 7402 package.

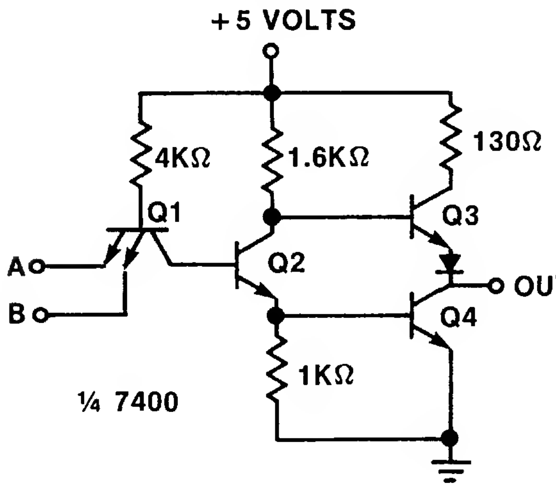
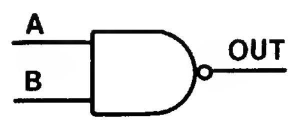


Figure 7.13. Conventional "Nand" Gate Function



A	B	OUT
0	0	1
0	1	1
1	0	1
1	1	0

Figure 7.14. Conventional "Nand" Gate Truth Table and Symbol

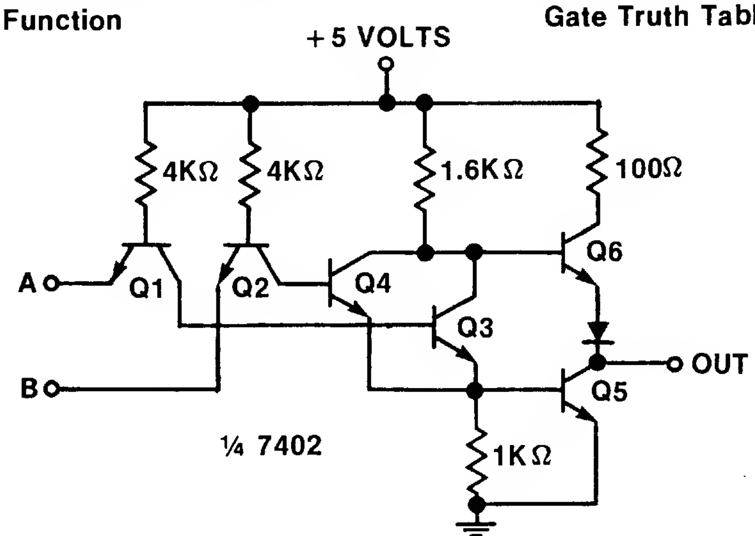


Figure 7.15. Conventional "Nor" Gate Function

A	B	OUT
0	0	1
0	1	0
1	0	0
1	1	0

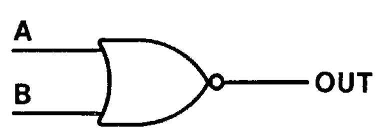
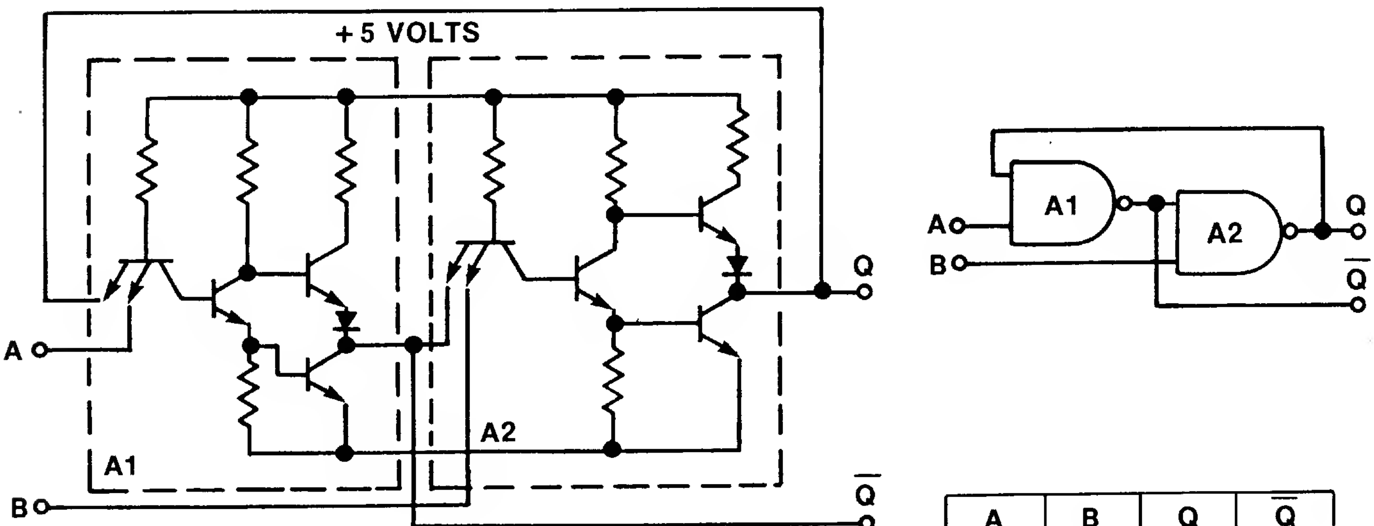
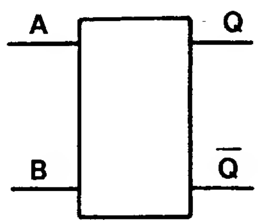


Figure 7.16. Conventional "NOR" Gate Truth Table and Symbol

The common set-reset flip-flop or latch may be constructed by tying two "nand" functions together as shown in Figure 7.17. In this case, two outputs are available, one called "Q" and one called "$\overline{Q}$". In normal operation, the two outputs will complement each other. If one is "high" the other will be "low". As shown in the truth table, asserting a low on the "A" input will cause the "$\overline{Q}$" output to go to a "high" condition. A "low" on the "B" input causes the "Q" output to go to a "high" condition. If **both** inputs are held high, an indeterminate state exists in which either output may be high with the restriction that the other output will be its complement. If both inputs are normally held high, a "low" pulse on the "B" input will set the "Q" output high. This state will continue until a low pulse on the "A" input resets the latch to cause the "Q" output to go low. Thus, used in this manner, the latch may be used to store a state, either a "1" or a "0". We stated in our discussion that "$\overline{Q}$" should always be the complement of "Q" and the first state of the truth table shows that with both inputs "low", both outputs will be "high". In most cases, this would be considered an illegal or disallowed state for the circuit. Set-reset latches may be assembled by tying together gates, and are now also available in prepackaged form (reference TTL 74279).



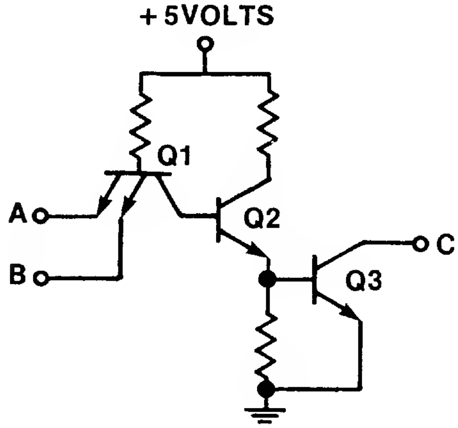


A	B	Q	$\overline{Q}$
0	0	1	1
0	1	0	1
1	0	1	0
1	1	X	X

Figure 7.17. Simple Set-Reset Latch

Another commonly used circuit or device is any of the devices discussed previously but utilizing a different output design, the "open-collector" output. An illustration would be an open-collector "2-input nand" as shown in Figure 7.18. In this case, transistor Q3 is utilized as a switch to isolate from, or connect to ground the output. This type of device finds many applications, including driving external circuits, often involving voltages much higher than the +5 volts used on the logic. The "open-collector" is also necessary when it is desired to "or" together the outputs of several devices as shown in Figure 7.19. This configuration creates a logic device commonly called a "wired-or" or a

"phantom-or" usually shown schematically as in the figure as the "or" symbol superimposed over the joined signal lines. The symbol may or may not be shown. Note that this configuration almost always requires the use of a pull-up resistor as shown. Otherwise, the voltage swing at the outputs may not be sufficient to drive the suceeding stage of logic.



A	B	CQ_3 (collector)
0	0	Hi
1	0	Hi
0	1	Hi
1	1	SATURATED Lo

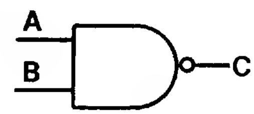


Figure 7.18. Open Collector "Nand"

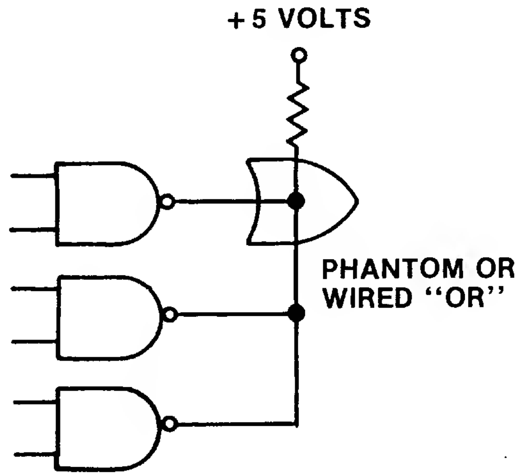


Figure 7.19. Open Collector "Nand" Symbol

As can be seen from the TTL device discussed previously, the inputs to most devices are the emitter connections of NPN transistors, thus the inputs are potential current sources. The current is limited typically, as in the circuit shown in Figure 7.20, by a series resistance, in this case 4K ohms. If an output is tied directly to ground, a current of about 1.6 milliamperes will flow through the emitter to ground connection. If not connected to anything, the input will rise or "float" to a positive level, and as far as the device is concerned, the input is high. Unfortunately, inputs which are just "floating" can act as an antenna and make the circuit noise sensitive. Unused inputs should properly be tied to the other like inputs of the gate or to an appropriate logic level, either ground or +5 volts. When connected to a logic high level, the emitter is back-biased and may accept a small amount of leakage current, typically about 40 microamperes.

The output of a typical device, when at a high logic level, must provide a current source sufficient to back-bias and provide leakage current to any inputs connected to it. The voltage level will typically rise to about 3.3 volts. If the output is low, it must provide a low-resistance path to ground for any inputs tied to it. Because TTL inputs accept minimum current but are capable of supplying current, and TTL outputs provide minimal current but are capable of passing to ground relatively large amounts of current, TTL is called current-sinking logic.

The outputs of TTL devices may be directly connected to the inputs of other TTL devices. The number of inputs which an output can accomodate is termed fan-out. Typical TTL devices have a fan-out of 10. That is, one output can accomodate up to ten inputs. Most TTL logic requires a high level input of at least = +2.4 volts and the low level must be as close to zero volts or ground as possible, usually no more than .8 volts. Levels which fall between these two levels may be interpreted by the device as either high or low. Because of the relatively large differences between high and low levels and the direct connection between inputs and outputs, TTL is relatively immune to noise when used in a properly designed circuit.

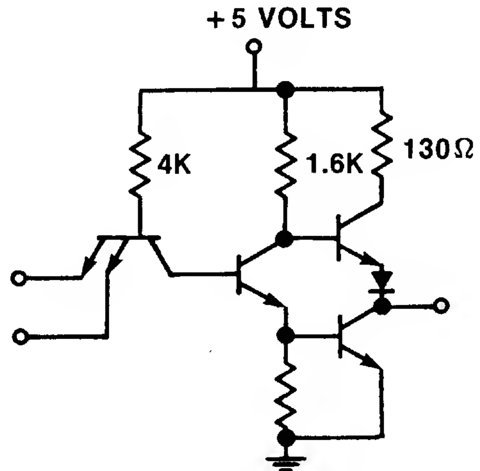


Figure 7.20. Typical "Nand" Circuit

7.2 PRACTICAL DIGITAL APPLICATION

After familiarity is gained with basic logic functions, the problem often arises of bridging the gap to practical application.

7.2.1 PACKAGING

The truth tables and data sheets show pin call out for chips as do schematics. In maintenance or troubleshooting, the problem then is to locate the desired pin on the integrated circuit package in question.

Most logic devices are contained in 14, 16 or 24 pin dip (dual in-line package) packages. Pin numbering for these dip packages is shown in Figure 7.21. These dip packages may be of moulded plastic or ceramic construction.

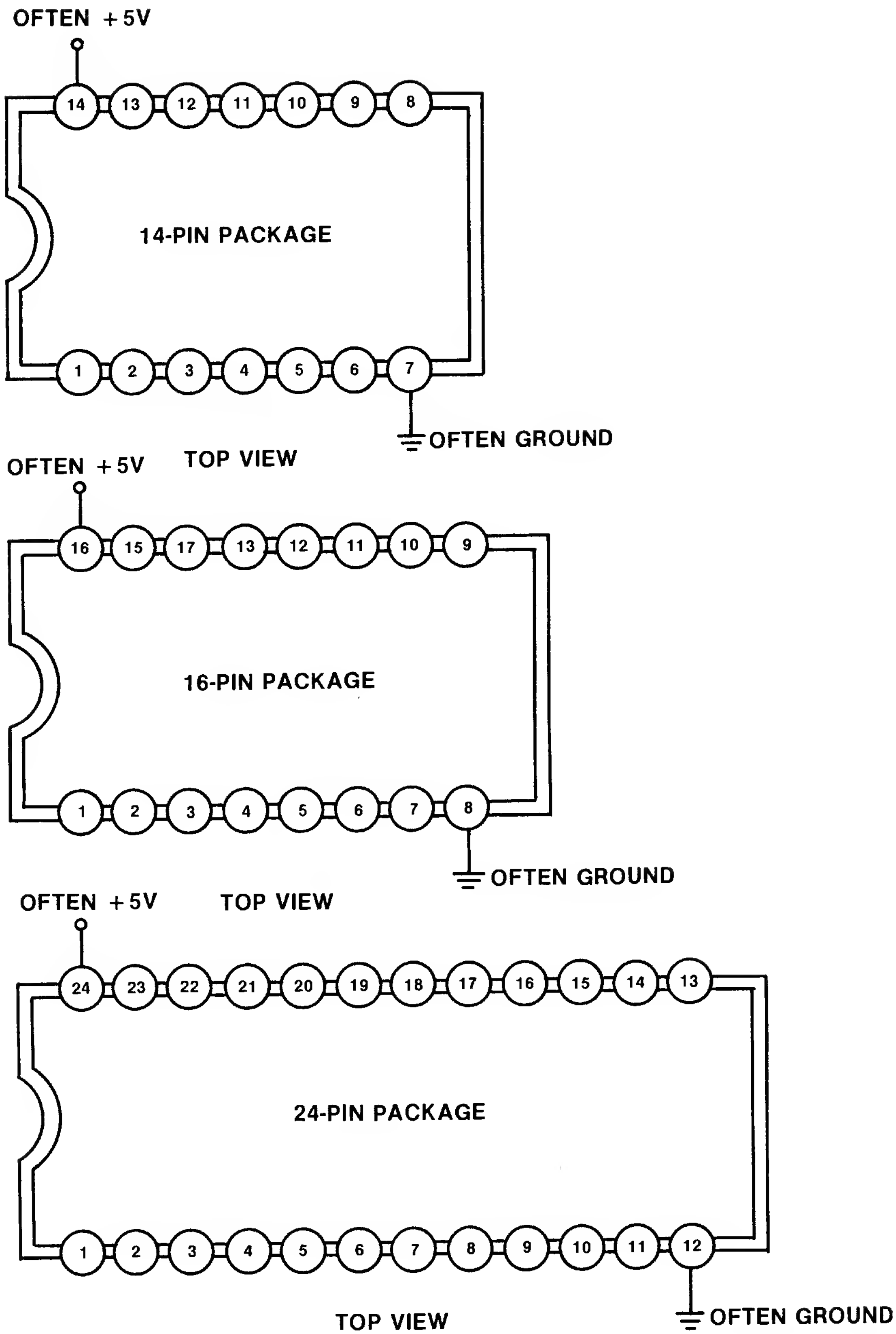


Figure 7.21. TTL Package Numbering

The next problem is locating Pin #1 which is the reference from which other pins are counted. Pin one may be marked in a number of ways as illustrated in Figure 7.22.

The example shown is looking down from the top. Chip sockets or mounting holes usually designate Pin One with a dot on the board next to Pin 1. Additionally, the socket itself may mark pin one or the correct insertion position, as in Figure 7.23.

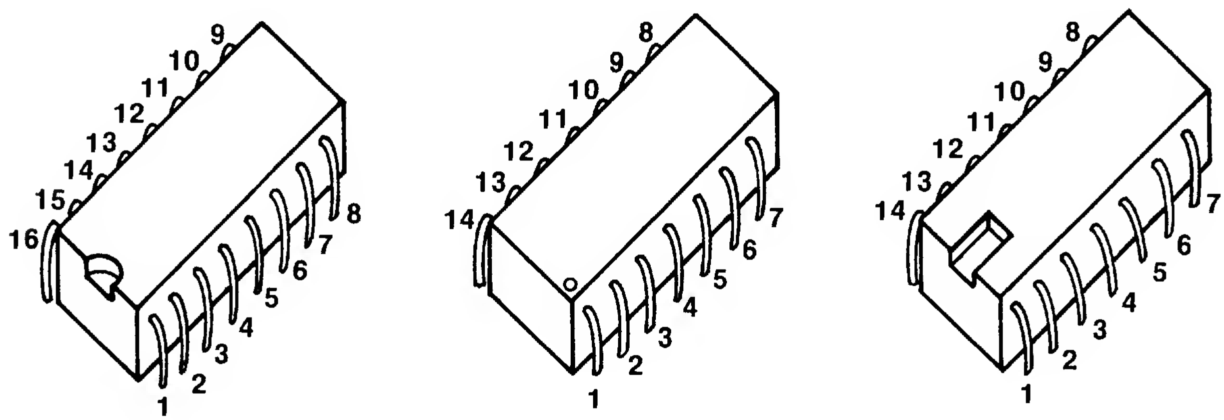


Figure 7.22. Chip Pin Designation

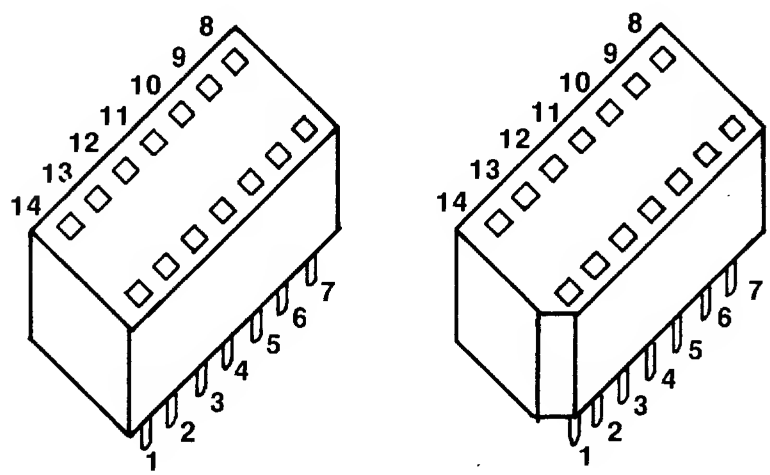


Figure 7.23. Socket Pin Out

Since Figures 7.22 and 7.23 show top views and pins are counted counterclockwise, working from the back of a panel or socket, the pins will be counted in a clockwise manner.

7.2.2 TTL LOGIC FAMILIES

Most TTL circuits discussed to this point have been what is termed regular TTL. There are a number of sub-families which trade off power consumption, speed and complexity for special purposes. These sub-families are called low-power TTL, high power TTL, schottky TTL and low-power schottky TTL.

The table in Figure 7.24 compares typical characteristics between sub-families of TTL and illustrates the usual numbering system used to identify sub-families and acceptable temperature ranges of operation.

Family	Gate Propagation time (nanosecs)	Power per Gate (milliwatts)	Max counter Frequency	-55° to +125°C	0° to 70°C
Regular TTL	10	10	35 MHz	5400	7400
High-Power TTL	6	22	50 MHz	54H00	74H00
Low-Power TTL	33	1	3 MHz	54L00	74L00
Schottky TTL	3	19	125 MHz	54S00	74S00
Low-Power Schottky TTL	10	2	45 MHz	54LS00	74LS0

Figure 7.24. Typical TTL Comparison

Regular TTL is normally the most widely available and lowest priced type TTL and has greatest variety and second sourcing. Typical gate-propagation time (the time it takes for a logic change at a gate input to appear at the output) is 10 nanoseconds. Dissipates about 10 milliwatts power per gate. Counting flip-flops can go up as high as 35 MegaHertz. Fan-out is normally 10 (Fan-out denotes the number of gates that can be driven by one output).

7.2.2.1 Low Power TTL - Exchanges power consumption for speed and is identified by a L in the part number. For instance, a 74L00 is a commercial low-power version of the regular TTL 7400 nand gate. There is about a 10:1 tradeoff, 1/10 the speed in counters vs 1/10 the power dissipation. Flip-flops and counters have a maximum toggle frequency of 3 MHz or so. Simpler gates may be ¼ the speed at 1/10 the power. Within low-power, fan-outs is 10, however a low-power TTL can drive only one regulat TTL gate.

7.2.2.2 High Power TTL - High power TTL devices are designated with an H on the part number. 74H00 is the equivalent of a 7400 and so on. Typically, you get twice the speed for twice the power. Counters are good to 50 MHz. Within the high-power family, fanout is 10. Fan-in is 1.3 times regular TTL, thus a regular TTL gate can handle at most, 7 high-power TTL inputs. High-power is by and large being replaced by the newer Schottky TTL which is faster and consumes less power.

7.2.2.3 Schottky TTL - Schottky TTL is an improved TTL that has better speed/power tradeoff than the older types. To do this, Schottky diodes (a fast diode with 0.3 volts forward drop) are placed across most transistors in the basic TTL gate. This prevents transistors saturating and thus eliminates storage time delays within the transistors. Part numbers have an S in them, as in 74S00. Propogation times of 3 nanoseconds are typical. Flip flops can run to 125 MHz.

7.2.2.4 Low Power Schottky TTL - The low power Schottky is a more recent variation of TTL. Schottky diodes combined with increased circuits impedances have produced a family slightly faster than regular TTL which requires only 1/5 the power.

Interchangeability or substitution between families is sometimes possible. Generally, a faster type may be substituted for a slower one. However, as mentioned, power requirements and fan-in, fan-out characteristics must also be considered. Because of this multiplicity of factors, no hard and fast rules can be made.

Figure 7.25 is a table of general TTL subfamily interfacing rules and Figure 7.26 gives input and out current characteristics.

Regular TTL	Will drive 10 regular TTL inputs Will drive 40 low-power TTL inputs Will drive 6 high-power TTL inputs Will drive 6 Schottky TTL inputs Will drive 20 low-power Schottky TTL inputs
Low-Power TTL	Will drive 2 regular TTL inputs Will drive 10 low-power TTL inputs Will drive 1 high-power TTL inputs Will drive 1 Schottky TTL input Will drive 5 low-power Schottky TTL inputs
High-Power TTL	Will drive 12 regular TTL inputs Will drive 40 low-power TTL inputs Will drive 10 high-power TTL inputs Will drive 10 Schottky TTL inputs Will drive 40 low-power Schottky inputs
Schottky TTL	Will drive 12 regular TTL inputs Will drive 40 low-power TTL inputs Will drive 10 high-power TTL inputs Will drive 10 Schottky TTL inputs Will drive 40 low-power Schottky TTL inputs
Low-Power Schottky TTL	Will drive 5 regular TTL inputs Will drive 20 low-power TTL inputs Will drive 4 high-power TTL inputs Will drive 4 Schottky TTL inputs Will drive 10 low-power Schottky TTL inputs

Figure 7.25. TTL Subfamily Fan-Out Rules

TTL Subfamily	Output Provides	Input Needs
Regular	16 mA	1.6 mA
High-Power	3.6 mA	0.18 mA
Low-Power	20 mA	2.0 mA
Schottky	20 mA	2.0 mA
Low-Power Schottky	8 mA	0.4 mA

Figure 7.26. TTL Input/Output Current

7.3 IC PROBLEMS

Logic chips are commonly sensitive to some problems. Because they are usually installed in sockets with multiple pins, poor contact of some pins may occur. Some chips legs and/or sockets are subject to corrosion especially in some machine equipment. Poor contacts or corrosion can cause noise sensitivity in chips. Also, some gates may float or be biased to indeterminate levels by leakage or voltages which may flow in the conductive paths which corrosion can produce.

Because of the basic design of TTL logic gates, fairly large amounts of current are drawn while a gate's output is making a transition between states. This requires good filtering of the power supply and a good distribution of despiking capacitors among all chips in an assembly, otherwise noise sensitivity may present severe problems. Very fast TTL such as Schottky, is especially critical in terms of circuit layout to be certain of noise resistance.

Some gates change value with age, such that input or output level swings no longer conform to normal "high" and "low" logic levels. This can also cause indeterminate or abnormal behavior. Some chips also develop temperature sensitivity with age such that, again, operating characteristics change.

7.3.1 IC PRECAUTIONS

Because of close pin location, it is easy if care is not taken, to short pins together which can destroy chips. This danger is particularly real when dealing with wire wrap paels. For this reason, insulated test clips such as safe-T-leads are highly desirable. If chip clips are used for test purposes, it is important to ascertain that the clip is installed securely and check pin numbers carefully, especially if a 16 pin clip is used on a 14 pin chip or vice versa. IC chips or assemblies should not be removed or inserted into equipment udner power on conditions, as this can damage equipment.

SECTION VIII

DIGITAL SIGNAL FLOW

8.1 INTRODUCTION

Digital logic is very versatile and can perform a number of functions. In this section the concepts of control logic functions, data control, and data flow will be discussed. Most of the newer DatagraphiX equipment utilizes one or both of the following conventions to identify digital signal paths. Digital signals may be either a high level or a low level. A signal which is in its active state when it is a high level, is identified with a signal name such as **STATUSRDY** or with a mnemonic signal name with a **P** suffix, such as **STSRDYP**. A signal which is active when a low level, is designated with a **NOT'ED** or **BAR'ED** signal name or with a mnemonic signal name using an **N** suffix, (examples, **$\overline{\text{STSREADY}}$** or **STSRDYN**). As stated, the signal or mnemonic identifies the signal path and the active state of the signal, either high or low. As an example, a signal line with the name **ALIGNP** is found to be a low level. This would indicate that the machine is not in alignment mode because the signal is not active. That is, the **P** suffix shows that the signal is high when active, so when low, the line is not active. This concept can also be thought of as a "true" or "false" condition, where the true state is active and the false state is inactive. A signal **XFORWARDN** is found to be low. This is the true or active state for the signal and would cause an X forward function. Very often, in a case such as this, if the same signal was found to be "high" (the false condition) this would cause the opposite of an X forward or an **XBACKWARD** function. In digital devices, an active signal will often be in the form of a pulse or short duration. For example, **RESETN**, if monitored, would exhibit a high condition (false) and only show a low pulse when reset is asserted.

Digital Data is most often in the form of "2 or more parallel signal lines, each of which carry a digital value", i.e., a high or a low. The combination of high and low signals (active and inactive) bits on the parallel lines represents some value, desired action or symbol. Commonly recognized groups of digital data bits, i.e., 1s and 0s, are called codes. Frequently utilized codes include **BCDIC** (Binary Coded Decimal Industry Compatible), **EBCDIC** (Extended **BCDIC**), and **ASCII** (American Standard Code for Information Interchange). These "standard" codes usually consist of 6 or 8 data bits. For example, the **EBCDIC** Code for the uppercase "A" is 11000001, eight digital bits. Codes such as this are commonly tabulated as in Figure 8.1. Note that each bit column in the table has a numerical designator (0 - 7) and that each code can also be expressed as a 2-character shorthand notation (Hexadecimal code). The code 11000001 can also be expressed as Hex "C1" and represents the upper case "A". This seemingly simple example introduces several important concepts. The first is that of the identified data bit.

The state of a signal or device is such that a binary value is represented, that is a high or low, a true or false condition, or a binary 1 or 0. Let us initially speak of a data bit. We will assign a mnemonic signal name **CATABIT O P**. If this signal is high, it represents a true state, a binary 1. If the same signal is low, it would represent a false state or a binary 0. If a signal named **DATA2N** is examined and found to be low, this is a true state for the signal and, again, represents a binary 1. Obviously a high for this signal would be a binary 0.

8-BIT CODE	HEXA-DECIMAL CODE	CHARACTER	8-BIT CODE	HEXA-DECIMAL CODE	CHARACTER	8-BIT CODE	HEXA-DECIMAL CODE	CHARACTER
00010011	13	TAPE MARK	10001111	8F	e	10111010	BA	$\underset{\circ}{+}$
01000000	40	BLANK	10010000	90	l	10111011	BB	δ
01001010	4A	¢	10010001	91	j	10111100	8C	1
01001011	4B	●	10010010	92	k	10111101	BD	1
01001100	4C	<	10010011	93	l	10111110	BE	-
01001101	4D	(	10010100	94	m	10111111	BF	-
01001110	4E	+	10010101	95	n	11000001	C1	A
01001111	4F	|	10010110	96	o	11000010	C2	B
01010000	50	&	10010111	97	p	11000011	C3	C
01011010	5A	|	10011000	98	q	11000100	C4	D
01011011	5B	$	10011001	99	r	11000101	C5	E
01011100	5C	*	10011010	9A	0 (plot circle)	11000110	C6	F
01011101	5D	)	10011011	9B	θ	11000111	C7	G
01011110	5E	;	10011100	9C	ϕ	11001000	C8	H
01011111	5F	¬	10011101	9D	° (Degrees)	11001001	C9	I
01100000	60	- (MINUS)	10011110	9E	–	11010001	D1	J
01100001	61	/	10011111	9F	~	11010010	D2	K
01101010	6A	\	10100000	A0	÷	11010011	D3	L
01101011	6B	,	10100001	A1	Σ	11010100	D4	M
01101100	6C	%	10100010	A2	s	11010101	D5	N
01101101	6D	– (UNDERSCORE)	10100011	A3	t	11010110	D6	O
01101110	6E	>	10100100	A4	u	11010111	D7	P
01101111	6F	?	10100101	A5	v	11011000	D8	Q
01111010	7A	:	10100110	A6	w	11011001	D9	R
01111011	7B	#	10100111	A7	x	11100000	E0	RECORD MARK
01111100	7C	@	10101000	A8	y	11100010	E2	S
01111101	7D	'	10101001	A9	z	11100011	E3	T
01111110	7E	=	10101010	AA	. (Plot Dot)	11100100	E4	U
01111111	7F	||	10101011	AB	≀	11100101	E5	V
10000000	80	Ω	10101100	AC	$\sqrt{\ }$	11100110	E6	W
10000001	81	a	10101101	AD	≠	11100111	E7	X
10000010	82	b	10101110	AE	≃	11101000	E8	Y
10000011	83	c	10101111	AF		11101001	E9	Z
10000100	84	d	10110000	B0	△	11110000	F0	0
10000101	85	e	10110001	B1	[	11110001	F1	1
10000110	86	f	10110010	B2	]	11110010	F2	2
10000111	87	g	10110011	B3	{	11110011	F3	3
10001000	88	h	10110100	B4	}	11110100	F4	4
10001001	89	i	10110101	B5	∧	11110101	F5	5
10001010	8A	↑	10110110	B6	λ	11110110	F6	6
10001011	8B	↓	10110111	B7	[ ]	11110111	F7	7
10001100	8C		10111000	B8		11111000	F8	8
10001101	8D	π	10111001	B9	ō	11111001	F9	9
10001110	8E		10111001			00000000	00	▮

Figure 8.1. Some EBCDIC Codes

Having seen how individual data bits are treated, lets next examine the more normal data configuration - several parallel bits. Using the **EBCDIC** code for upper case "A", we see 8 bits which are examined simultaneously to recognize the code. In a machine, each bit or data line would have a name, so lets assign one:

NAME	**BIT0P**	**BIT1P**	**BIT2P**	**BIT3P**	**BIT4P**	**BIT5P**	**BIT6P**	**BIT7P**
Binary Value	1	1	0	0	0	0	0	1
Signal Level	Hi	Hi	Lo	Lo	Lo	Lo	Lo	Hi

These eight signals or bits when simultaneously examined as an ordered group, are called a "byte". The byte represents the **EBCDIC** code for the printable character upper case "A". This character and the binary bits representing it may also be indicated for simplicity sake as "C1" in Hexadecimal notation. Hex notation is a means of representing the binary bits in a data byte without the necessity of writing out all of the 1s and 0s. Hex is based on groups of four bits within the data byte. The byte is subdivided into two groups of four bits each. Each four bit group is then represented by a single character. A four bit group, wherein each bit may be either a 1 or 0, allows sixteen different combinations, from all bits being 0 to all being 1. These combinations can represent decimal values if each bit is assigned a binary based decimal value. With four bits, the values would be assigned from left to right - 8 4 2 1. The bits may then represent decimal values from 0 to 15. For example $\overset{8\,4\,2\,1}{0\,0\,0\,0}$ = Decimal 0. $\overset{8\,4\,2\,1}{0\,0\,0\,1}$ = decimal 1 (the only true bit is the one value bit). $\overset{8\,4\,2\,1}{0\,0\,1\,0}$ = decimal 2 (the only bit marked is the 2 value bit). $\overset{8\,4\,2\,1}{0\,0\,1\,1}$ = decimal 3 (the 1 and 2 bits are ture). $\overset{8\,4\,2\,1}{1\,0\,1\,0}$ = decimal 10 (the 2 and 8 bits are true). $\overset{8\,4\,2\,1}{1\,1\,1\,1}$ = decimal 15 (all bits are true). Hexadecimal notation uses a single character to represent each four bit combination. See Table 8.2 (Figure 8.2.)

BITS	DECIMAL	HEX
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

Figure 8.2. Hexadecimal Notation

By breaking each eight bit code byte into two subgroups, the eight bit code can now be represented by 2 characters. Example: The code for upper case "A" (11000001) may be represented as follows: break into two groups 1100 and 0001. The first group comes out to a decimal 12 or a hex C. The second four bits come out to a decimal 1 or hex 1. The hex code then is "C1". In many cases, when discussing codes it is much more convenient to use hex notation than to rattle off a long string of 1s and 0s.

Digital data handling, the manipulating of coded data bytes, requires certain considerations and restrictions. The first is that, as mentioned, codes are groups of ordered bits examined simultaneously. These bits are usually handled on parallel lines, thus if a byte of data is transferred over signal lines from one place to another and then examined, it is important that data is not examined until it is ascertained that the data for all signal lines has arrived. One method of data transfer quite common with digital equipment is the use of control signals to accomplish the actual transfer of data from one location to another. To simplify this concept, let us examine Figure 8.3, a circuit capable of accepting and storing a single data bit. This is constructed of logic gates of the type which were discussed in the previous section. The gates are configured as a simple set-reset flip-flop composed of gates 3 and 4 which can only be changed by going through 1, 2 and 5. The data which it is desired to store is placed on input "D" but can only effect the RS flip-flop when a high level is applied to input "C". A truth table for this device is shown in Figure 8.4. This device would normally be used by applying data to the "D" input and then using a high level control pulse on "C" to load the data into the flip-flop. The table shows that when the "C" input is high, the output is set to agree with the "D" input. If the C input is low and the D input is high or low, the output is unaffected. The Q and $\overline{Q}$ outputs will stay in the last state loaded into the flip flop, and the two outputs will be complementary. That is, if "Q" is high, "$\overline{Q}$" will be low, or vice versa.

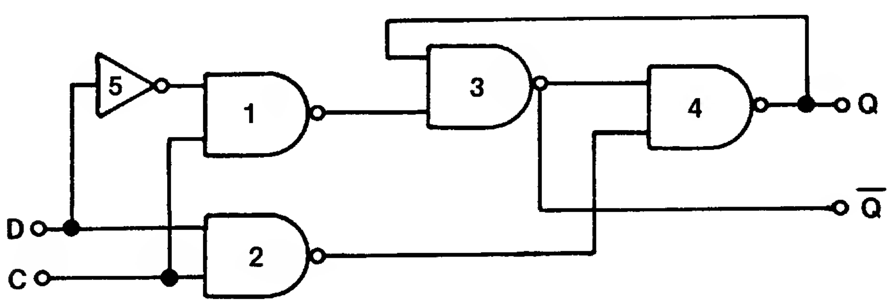
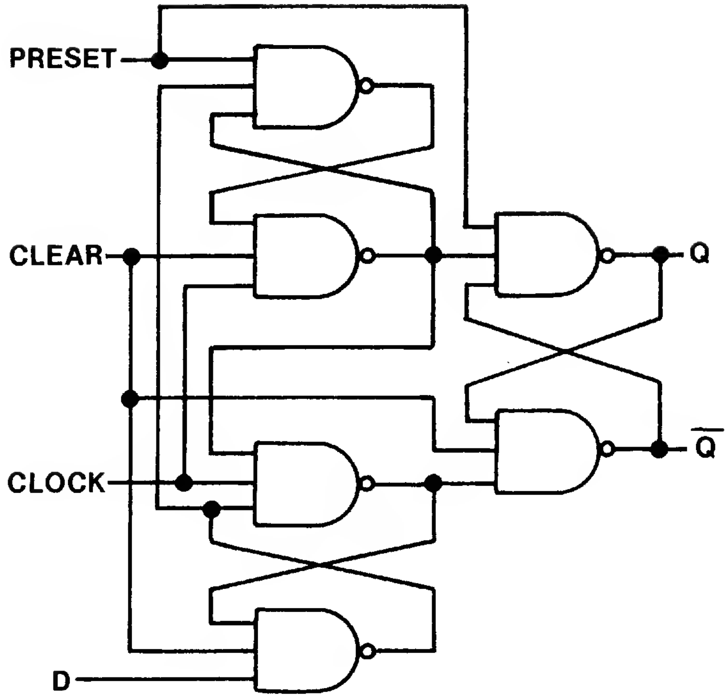


Figure 8.3. Simple "Gated" Flip-Flop Function

D	C	Q	$\overline{Q}$
0	0	X	$\overline{X}$
0	1	0	1
1	1	1	0
1	0	X	$\overline{X}$

Figure 8.4. Truth Table

A somewhat more complex device utilizing a combination of 3-input nand gates is shown in Figure 8.5. The "nands" are configured into what is called a D-type flip-flop, an elaboration of the device just discussed. This device has two additional inputs - a preset and a clear. The "preset" input can set the output so that Q is high and $\overline{Q}$ is low. "Clear" can reset the flip flop so that Q is low and $\overline{Q}$ is high. As shown in the truth table, the present and clear inputs are active when low. If both are asserted at the same time, a logically illegal state exists. When the "C" input is low, the output is stable at whatever data was stored when "C" was last high, unless this is overridden by the clear or preset input. A similar device is commercially available as a packaged logic device. Reference the logic symbol shown, note the inverting "bubbles" on the preset and clear inputs showing that these are active low levels. Reference this device to the 7474 packaged D-type flip-flop.



D	CD	PRESET	CLEAR	Q	Q	
X	L	H	H	X	$\overline{X}$	**INDETERMINATE**
X	X	L	H	H	L	
X	X	H	L	L	H	
X	X	L	L	H	H	**INVALID STATE**
L	H	H	H	L	H	
H	H	H	H	H	L	

Figure 8.5. "D" Type Flip-Flop Function

When a data byte is transferred into a storage or processing register or buffer, it is often desirable to check the data for a specific code or codes, for example, in the circuit in Figure 8.6.A, Data is loaded into the eight D-type flip flops with the **LOADATAP** signal. When held in the register, the data is checked for presence of two **EBCDIC** codes. Gate J, an eight input "nand" is wired to respond to a hex "C1". The **EBCDIC** code for the character upper case "A". Hex "C1" is binary 11000001, which means that bits 0, 1 and 7 must be 1s and all others must be 0s. This is the condition which will cause the output of Gate J to go to a true level, "**ACODEN**" low. Any other combination of data bits will cause the output of Gate J to remain high (false). Gate K is wired to decode the Hex code 4E, which is the **EBCDIC** code for the plus symbol (+).

A further refinement of the flip-flop data storage or logic device is the J-K Master-Slave flip-flop, Figure 8.6.B shows how the device would be constructed using logic gates, with which we are already familiar. In this case, there are two data or stepping inputs, J and K. Plus clock input and preset and clear. The J and K inputs can only effect the outputs when acted upon by a clock pulse.

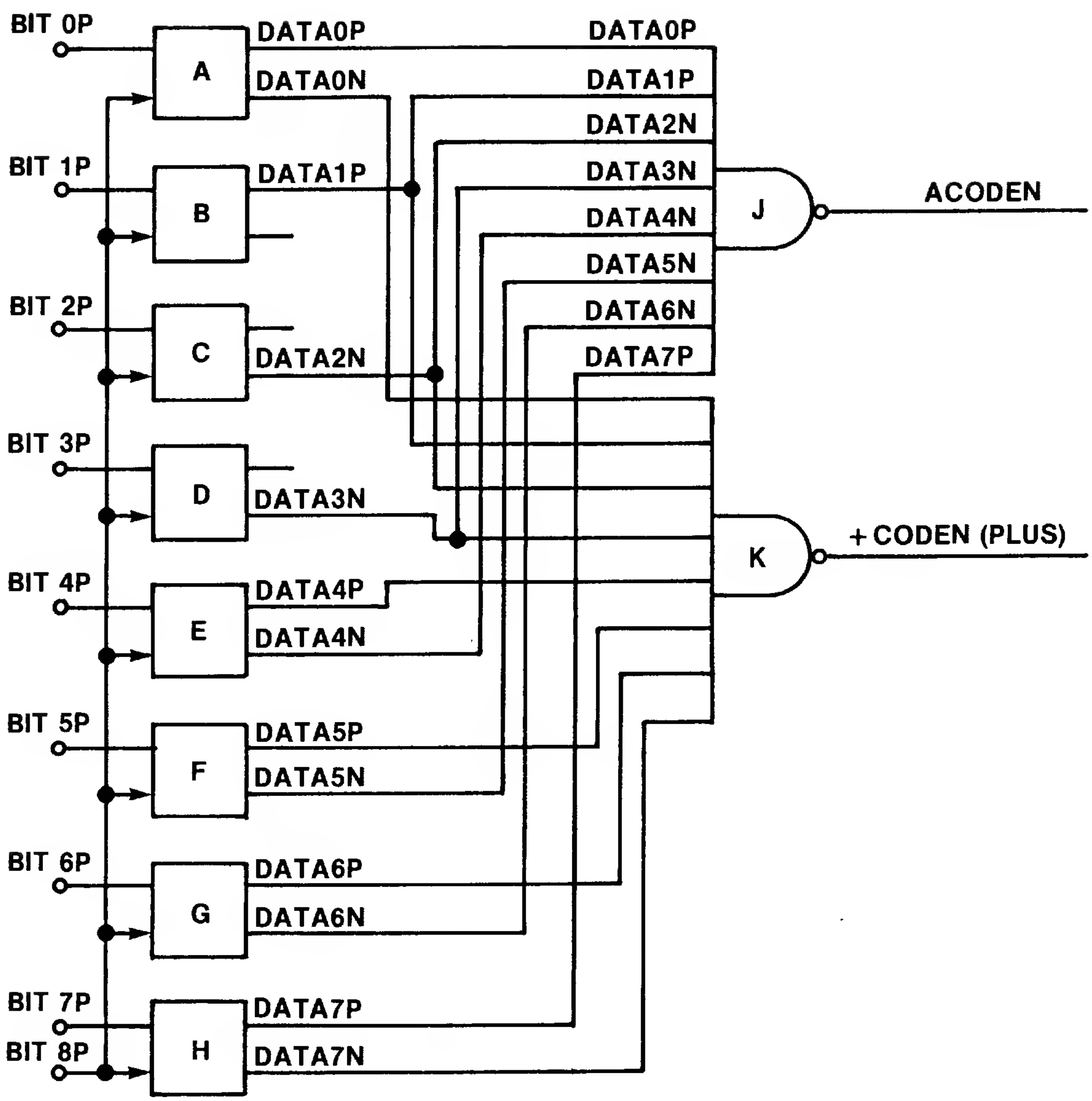


Figure 8.6.A Decoding Gates

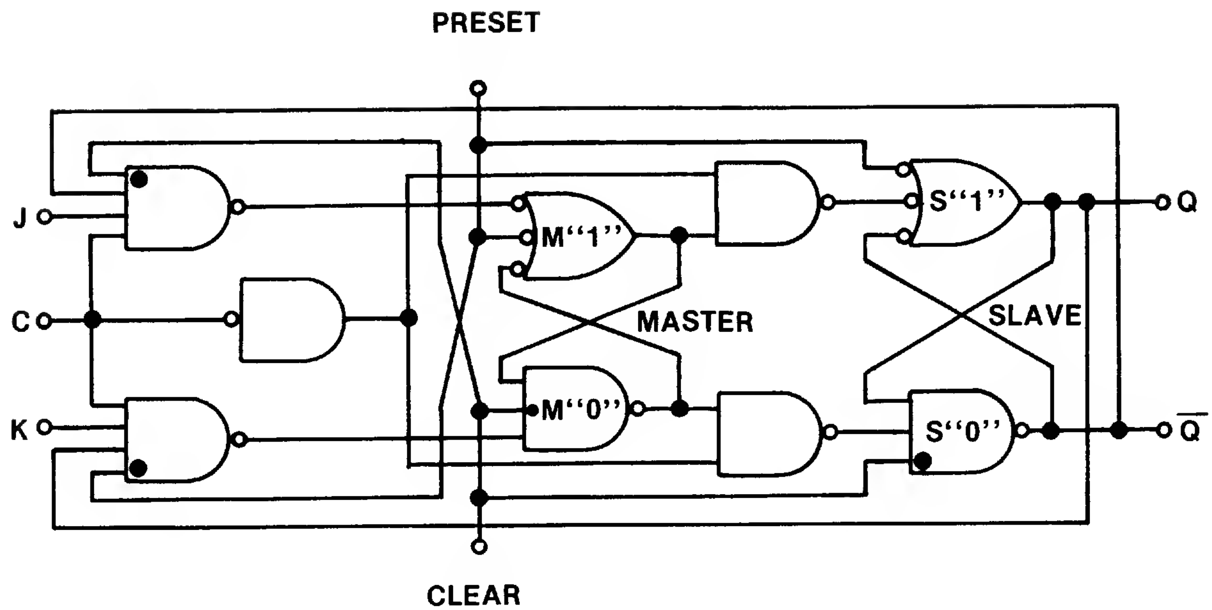


Figure 8.6.B Logical Representation of the J-K Master-Slave Flip-Flop

Figure 8.6.C shows typical descriptive alternative for two such devices, the 7476 and 7478 J-K master-slave flip-flops, including pin-callout, packaging information, common logic symbol and truth tables.

Combining these more complex devices with more simple gates and putting all into a single package make increasingly sophisticated logic possible. Figure 8.6.D is a description of such a device, the 74197. This device can function as either a latch for data storage or a counter for counting data pulses.

When data bytes are transferred from one locaion to another, it is very common to use what is called a handshake. That is logic signals passing between the data source and data destination. These signals are used to coordinate and accomplish the data transfer. This type arrangement could include any or all of the functions as illustrated in Figure 8.7.

1. A status line from source to destination indicating that data is available. **(DATAVAILABLEN)**

2. A signal from destination to source (**DATAREQUESTN**), to indicate that space is available to receive data.

3. A signal from source to destination indicating that data has been placed on line, and often used to accomplish the actual transfer (**DATASENTN** or **DATACLOCKN**).

4. Confirmation of receipt of data, completion of transfer (**DATARECEIVEDN**).

76

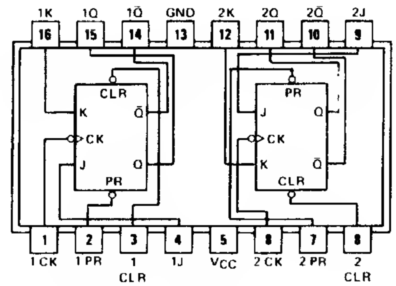
DUAL J-K FLIP-FLOPS WITH PRESET AND CLEAR

'76, 'H76
FUNCTION TABLE

INPUTS					OUTPUTS	
PRESET	CLEAR	CLOCK	J	K	Q	$\bar{Q}$
L	H	X	X	X	H	L
H	L	X	X	X	L	H
L	L	X	X	X	H*	H*
H	H	⎍	L	L	Q_0	$\bar{Q}_0$
H	H	⎍	H	L	H	L
H	H	⎍	L	H	L	H
H	H	⎍	H	H	TOGGLE	

'LS76
FUNCTION TABLE

INPUTS					OUTPUTS	
PRESET	CLEAR	CLOCK	J	K	Q	$\bar{Q}$
L	H	X	X	X	H	L
H	L	X	X	X	L	H
L	L	X	X	X	H*	H*
H	H	↓	L	L	Q_0	$\bar{Q}_0$
H	H	↓	H	L	H	L
H	H	↓	L	H	L	H
H	H	↓	H	H	TOGGLE	
H	H	H	X	X	Q_0	$\bar{Q}_0$



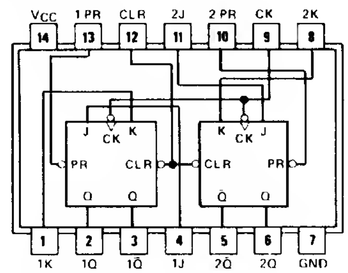
SN5476/SN7476(J, N, W)
SN54H76/SN74H76(J, N, W)
SN54LS76/SN74LS76(J, N, W)

78

DUAL J-K FLIP-FLOPS WITH PRESET, COMMON CLEAR, AND COMMON CLOCK

'H78, 'L78
FUNCTION TABLE

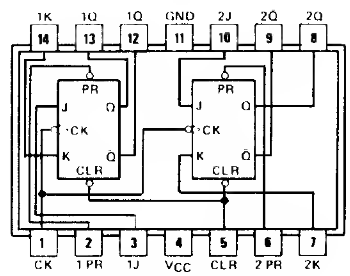
INPUTS					OUTPUTS	
PRESET	CLEAR	CLOCK	J	K	Q	$\bar{Q}$
L	H	X	X	X	H	L
H	L	X	X	X	L	H
L	L	X	X	X	H*	H*
H	H	⎍	L	L	Q_0	$\bar{Q}_0$
H	H	⎍	H	L	H	L
H	H	⎍	L	H	L	H
H	H	⎍	H	H	TOGGLE	



SN54H78/SN74H78(J, N, W)

'LS78
FUNCTION TABLE

INPUTS					OUTPUTS	
PRESET	CLEAR	CLOCK	J	K	Q	$\bar{Q}$
L	H	X	X	X	H	L
H	L	X	X	X	L	H
L	L	X	X	X	H*	H*
H	H	↓	L	L	Q_0	$\bar{Q}_0$
H	H	↓	H	L	H	L
H	H	↓	L	H	L	H
H	H	↓	H	H	TOGGLE	
H	H	H	X	X	Q_0	$\bar{Q}_0$



SN54L78/SN74L78(J, N, T)
SN54LS78/SN74LS78(J, N, W)

H = high level (steady state), L = low level (steady state), X = irrelevant

⎍ = high-level pulse; data inputs should be held constant while clock is high; dtat is transferred to output on the falling edge of the pulse

↓ = transition from high to low level

Q_0 = the level of Q before the indicated input conditions were established

TOGGLE: Each output changes to the complement of its previous level on each active transition (pulse) of the clock

***This configuration is nonstable; that is, it will not persist when preset and clear inputs return to their inactive (high) state.**

Figure 8.6.C. 54/74 Families of Compatible TTL Circuits

DESCRIPTION - The 93196/54196, 74196 and 93197/54197, 74197 High Speed Counters will provide either a divide-by-two and a divide-by-five counter (93196/54196, 74196) or a divide-by-two and a divide-by-eight counter (93197/54197, 74197). The counters are fully presettable to any output state by placing a **LOW** on the count/load input and entering the desired data at the data inputs. The outputs will change to agree with the data inputs regardless of the state of the clocks.

These counters may also be used as 4-bit latches by using the count/load input as the strobe and entering data at the data inputs. The outputs will directly follow the data inputs when the count/load is **LOW**, but will remain unchanged when the count/load is **HIGH** and the clock inputs are inactive.

These high speed counters will accept count frequencies of 0 to 50 MHz at the clock 1 input and 0 to 25 MHz at the clock 2 input. During the count operation, transfer of information to the output occurs on the negative-going edge of the clock pulse. These counters feature a direct clear which, when taken **LOW**, sets all outputs **LOW** regardless of the states of the clocks.

All inputs are diode-clamped to minimize transmission-line effects and simplify system design. Typical power dissipation is 240 mW.

93197/54197, 74197

The output of flip flop A is not internally connected to the succeeding flip-flops, therefore the counter may be operated in two independent modes:

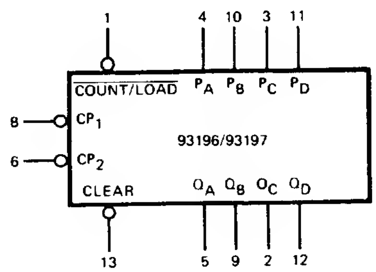
1. When used as a high speed 4bit ripple counter, output Q_A must be externally connected to the clock 2 input. The input count pulses are applied to the clock 1 input. Simultaneous divisions by 2, 4, 8 and 16 are performed at the Q_A, Q_B, Q_C, Q_D output as shown in the truth table at the right.

2. When used as a 3-bit ripple counter, the input count pulses are applied to the clock 2 input. Simultaneous frequency divisions by 2, 4 and 8 are available at the Q_B, Q_C, and Q_D outputs independent use of flip-flop is available if the load and clear functions coincide with those of the 3-bit ripple counter.

PIN NAMES		LOADING (Note a)
P_A, P_B, P_C, P_D	Parallel Inputs	1 U.L.
$\overline{CP_1}, \overline{CP_2}$	Clock Inputs (Note b)	2 U.L.
$\overline{CLEAR}$	Clear Input	2 U.L.
$\overline{COUNT/LOAD}$	Count Load Input	1 U.L.
Q_A, Q_B, Q_C, Q_D	Parallel Outputs	10 U.L.

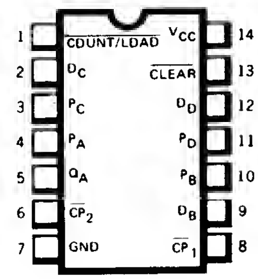
NOTES:
(a) 1 U.L. = 40 μA HIGH/1.6 mA LOW
(b) $\overline{CP_2}$ – 3 U.L. on 93196

LOGIC SYMBOL

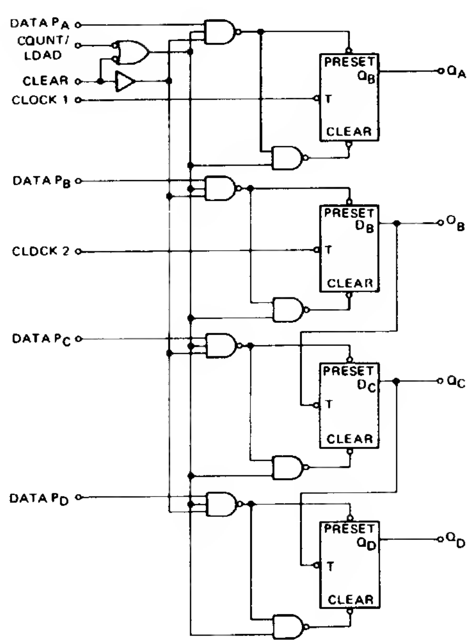


V_{CC} = Pin 14
Gnd = Pin 7

CONNECTION DIAGRAM
DIP (TOP VIEW)



93197/54197, 74197



COUNT	Q_D	Q_C	Q_B	Q_A
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	L	H	L	H
6	L	H	H	H
7	L	H	H	H
8	H	L	L	L
9	H	L	L	H
10	H	L	H	L
11	H	L	H	H
12	H	H	L	L
13	H	H	L	H
14	H	H	H	L
15	H	H	H	H

Figure 8.6.D. TTL/MSI 93197/54197, 74197 High Speed Binary Counter

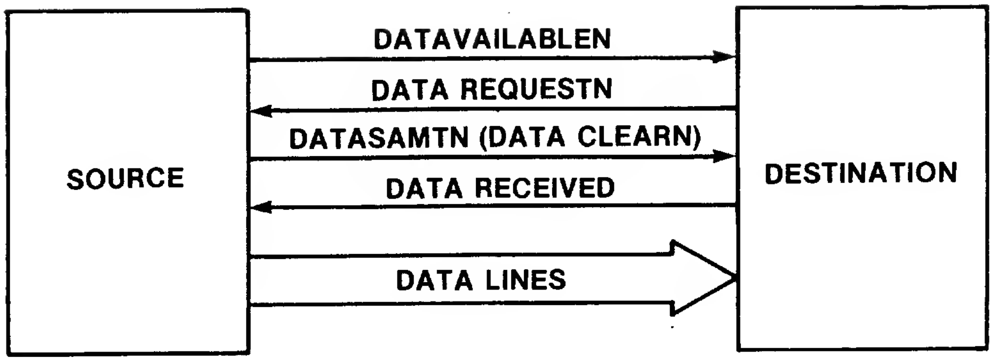


Figure 8.7. Handshake Examples

Figure 8.7.A shows data sheets for several common one-shots (mono-stable - multivibrators) both normal and retriggerable, as indicated by the devices result in a pulse as determined by externally installed R/C components. In a retriggerable device if the devices input(s) are satisfied before the output has reset, the timing period restarts from that point, so long as pulses keep coming in the output stays active.

When a series of data bits is coming into or passing through a device at some known rate, it is often desirable to determine when this data flow ceases. A device commonly used to perform this function is the gap detectgor or retriggerable one-shot. The retriggerable one-shot will recommence its timing period if exposed to another trigger pulse prior to having timed out. If the time period of the one-shot is set to some value greater than the normal data rate, so long as data passes at the normal rate, the one-shot remains "set". Only when data ceases or fails to arrive within the prescribed period will the one-shot time out, thus detecting a gap in the data. One-shots are frequently used to monitor data flow in tape units and for many other applications.

It is often necessary to generate pulses or clocks to perform data handling or logic functions within a machine. A clock or timing source can be as simple as a pair of one-shots tied together so that each will trigger the other. This will produce a repetitive waveform, the frequency of which can be varied by adjusting the time periods of the one-shots. Such a clock is illustrated in Figure 8.8. The cross coupled one-shots produce a square wave signal which is then fed into the counter chip V6, which counts down and produces clocks at ½, 1 and 2 microsecond rates.

When data is stored or transferred, it is common to add an additional data bit for purposes of error detection. This bit is usually called a parity bit as discussed in the section of magnetic tape. Most commonly, the parity bit is marked such that the total of the 1s bits in the data is always an odd or an even number. For example, the hex code "C1" (**EBCDIC** code for "A") bits are 11000001. The number of 1 bits is odd, therefore, if odd parity were the desired mode, the parity bit for this byte would be marked as a "0". For the hex code "C3" (**EBCDIC** code for uppercase "C") the bits are 11000011. The number of 1 bits is even, so the parity bit for this byte would be marked as a "1" to make the parity of the total odd as desired. When retrieving data from storage or after a transfer, the total byte including the parity bit would be examined to check for correct parity. This check is usually called the vertical redundancy check, or VRC.

MONOSTABLE MULTIVIBRATORS

121

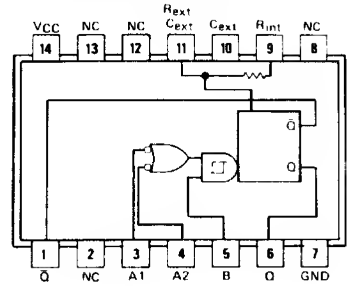
FUNCTION TABLE

INPUTS			OUTPUTS	
A1	A2	B	Q	$\bar{Q}$
L	X	H	L	H
X	L	H	L	H
X	X	L	L	H
H	H	X	L	H
H	↓	H	⎍	⊔
↓	H	H	⎍	⊔
↓	↓	H	⎍	⊔
L	X	↑	⎍	⊔
X	L	↑	⎍	⊔

See Notes

SN54121/SN74121(J, N, W)
SN54L121/SN74L121(J, N, T)
'121 . . . R_{int} = 2 kΩ NOM
'L121 . . . R_{int} = 4 kΩ NOM

NC—No internal connection

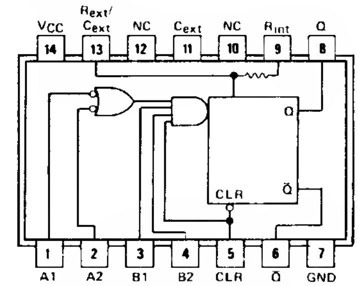


RETRIGGERABLE MONOSTABLE MULTIVIBRATORS WITH CLEAR

FUNCTION TABLE

INPUTS					OUTPUTS	
CLEAR	A1	A2	B1	B2	Q	$\bar{Q}$
L	X	X	X	X	L	H
X	H	H	X	X	L	H
X	X	X	L	X	L	H
X	X	X	X	L	L	H
X	L	X	H	H	L	H
H	L	X	↑	H	⎍	⊔
H	L	X	H	↑	⎍	⊔
H	X	L	H	H	L	H
H	X	L	↑	H	⎍	⊔
H	X	L	H	↑	⎍	⊔
H	H	↓	H	H	⎍	⊔
H	↓	↓	H	H	⎍	⊔
H	↓	H	H	H	⎍	⊔
↑	L	X	H	H	⎍	⊔
↑	X	L	H	H	⎍	⊔

See Notes



SN54122/SN74122(J, N, W)
SN54L122/SN74L122(J, N, T)
'122 . . . R_{int} = 10 kΩ NOM
'L122 . . . R_{int} = 20 kΩ NOM

NC—No internal connection

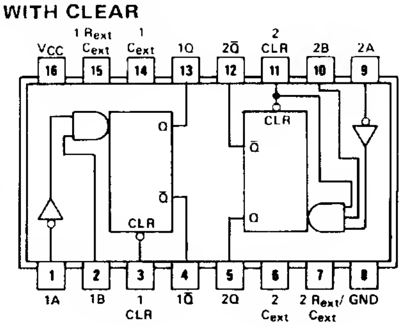
DUAL RETRIGGERABLE MONOSTABLE MULTIVIBRATORS WITH CLEAR

FUNCTION TABLE

INPUTS			OUTPUTS	
CLEAR	A	B	Q	$\bar{Q}$
L	X	X	L	H
X	H	X	L	H
X	X	L	L	H
H	L	↑	⎍	⊔
H	↓	H	⎍	⊔
↑	L	H	⎍	⊔

See Notes

SN54123/SN74123(J, N, W)
SN54L123/SN74L123(J, N)



NOTES:

A. H = high level (steady state), L = low level (steady state), ↑ = transition from low to high level, ↓ = transition from high to low level, ⎍ = one high-level pulse, ⊔ = one low-level pulse, X = irrelevant (any input, including transitions).

B. To use the internal timing resistor of 121, L121, 122, or L122, connect R_{int} to V_{CC}.

C. An external timing capacitor may be connected between C_{ext} and R_{ext}/C_{ext}(positive).

D. For accurate repeatable pulse widths, connect an external resistor between R_{ext}/C_{ext} and V_{CC} with R_{int} open-circuited.

E. To obtain variable pulse widths, connect external variable resistance between R_{int} or R_{ext}/C_{ext} and V_{CC}.

Figure 8.7.A. 54/74 Families of Compatible TTL Circuits

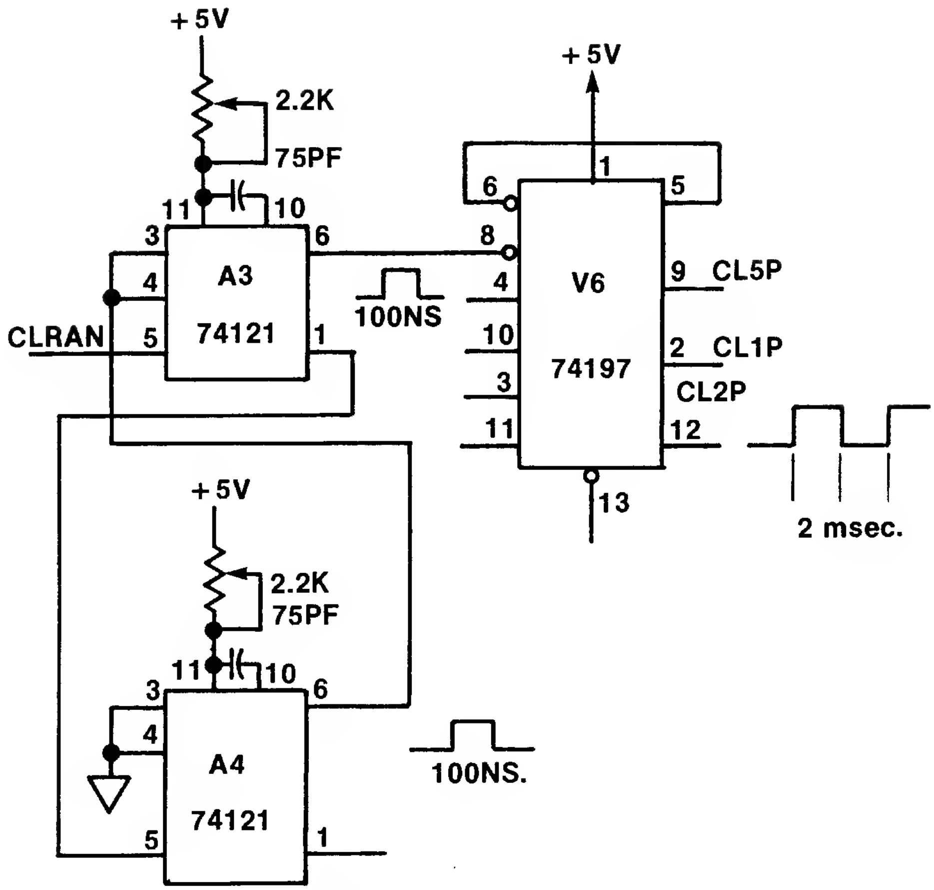


Figure 8.8. Clock Generator

Another frequent requirement is to produce a certain number of pulses at a specified interval following a command. Figure 8.9 is a schematic for a 2-pulse generator. After a low going pulse (**STARTSTRBN**) is applied to L4 - Pin 1, and released, two pulses are produced at the output (**STRP**).

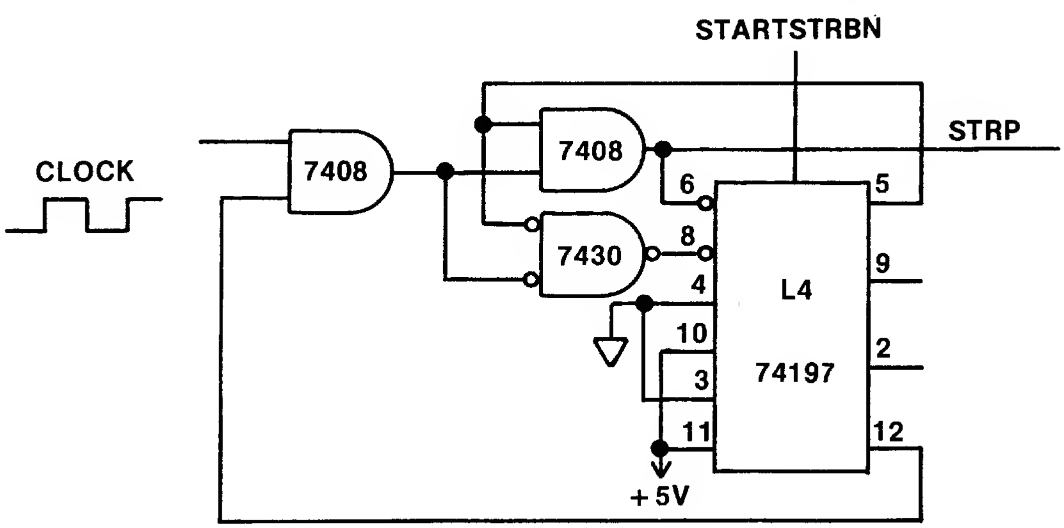


Figure 8.9. Two-Pulse Generator

SECTION IX

SCOPING DIGITAL CIRCUITS

9.1 CIRCUIT RECOGNITION

This section consists of several exercises in circuit recognition. The object being to learn how to determine what you would expect to see when scoping or troubleshooting in a digital circuit.

The circuits shown are real circuits used in production machines. In each case, accompanying instructions will state what is desired for the student to determine. As a simple demonstration, observe the following circuit, Figure 9.1.

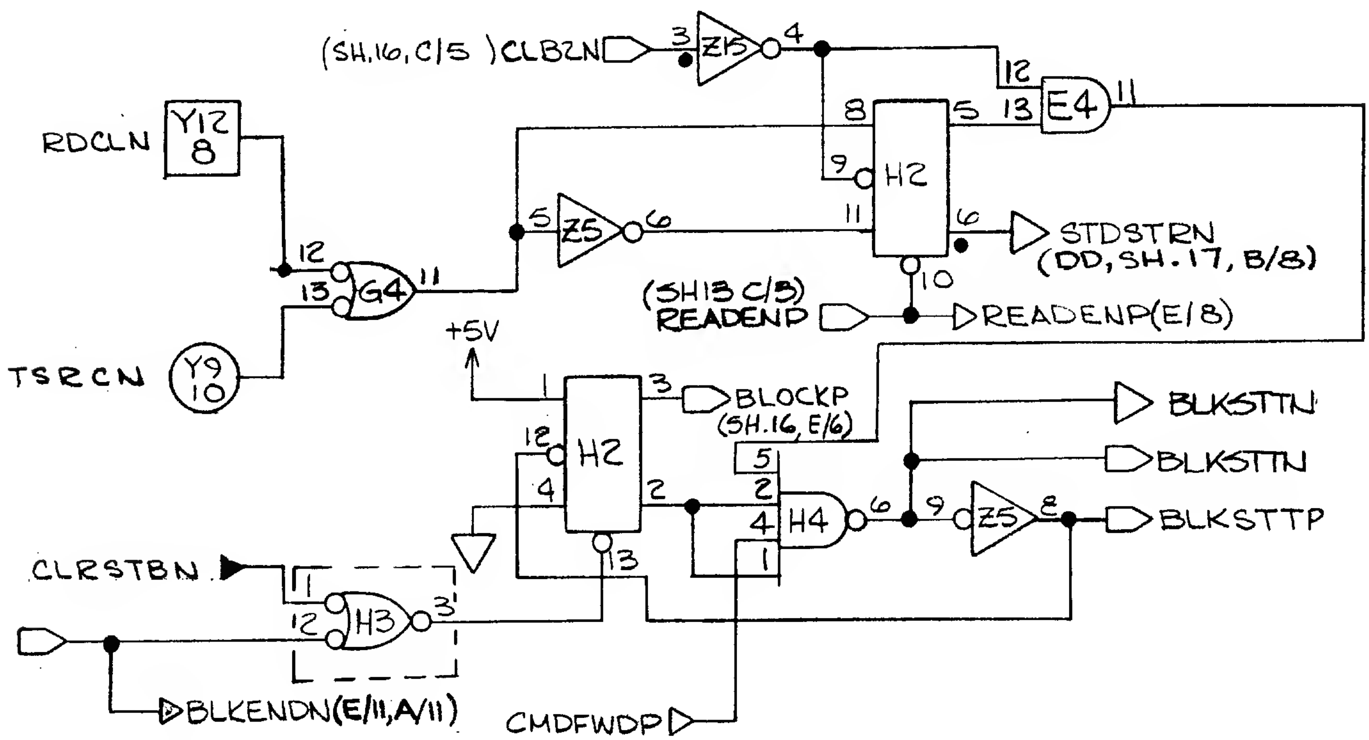


Figure 9.1 Demonstration Circuit

Using the given values as shown on page 70 for **CLB2N, RDCLN, TSRCN, CMDFWDP, BLKENDN,** show what you would expect to see at **STDSTRN**, Block P, **BLKSTTN**.

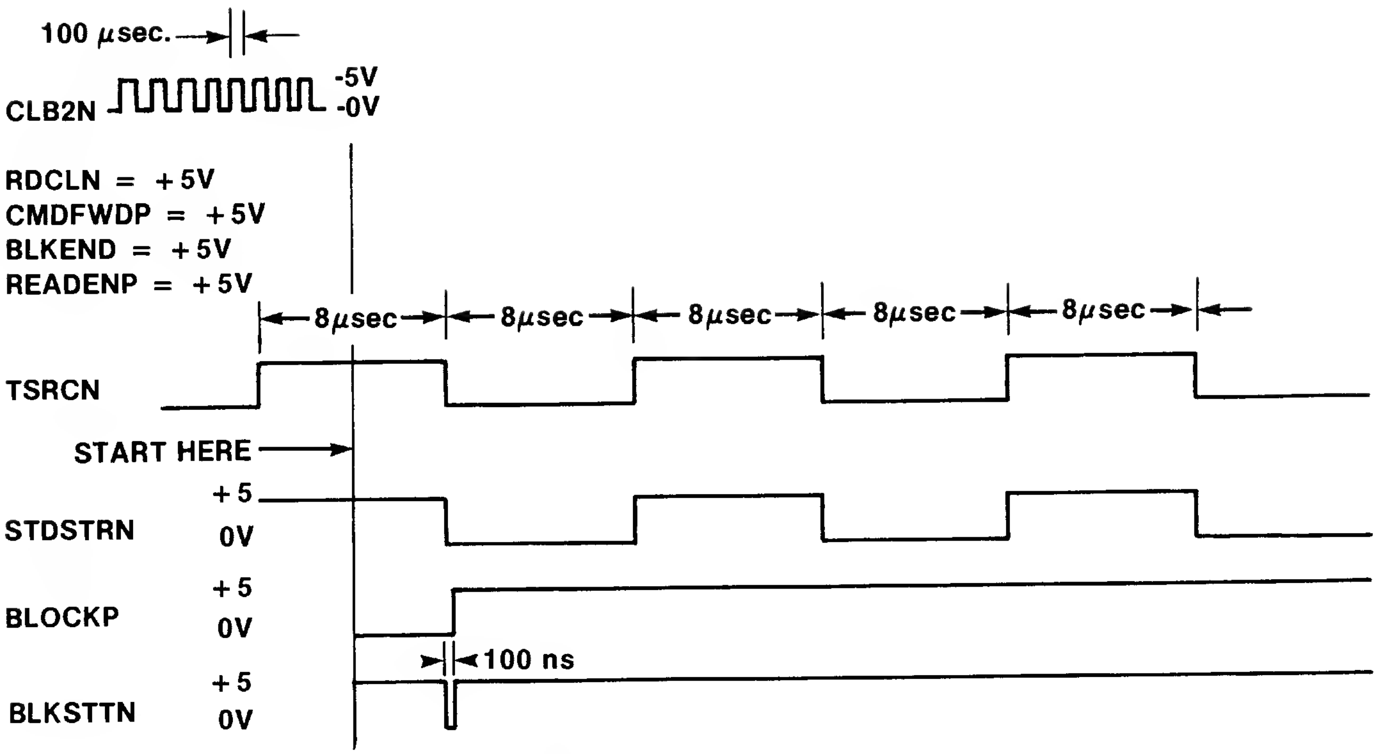
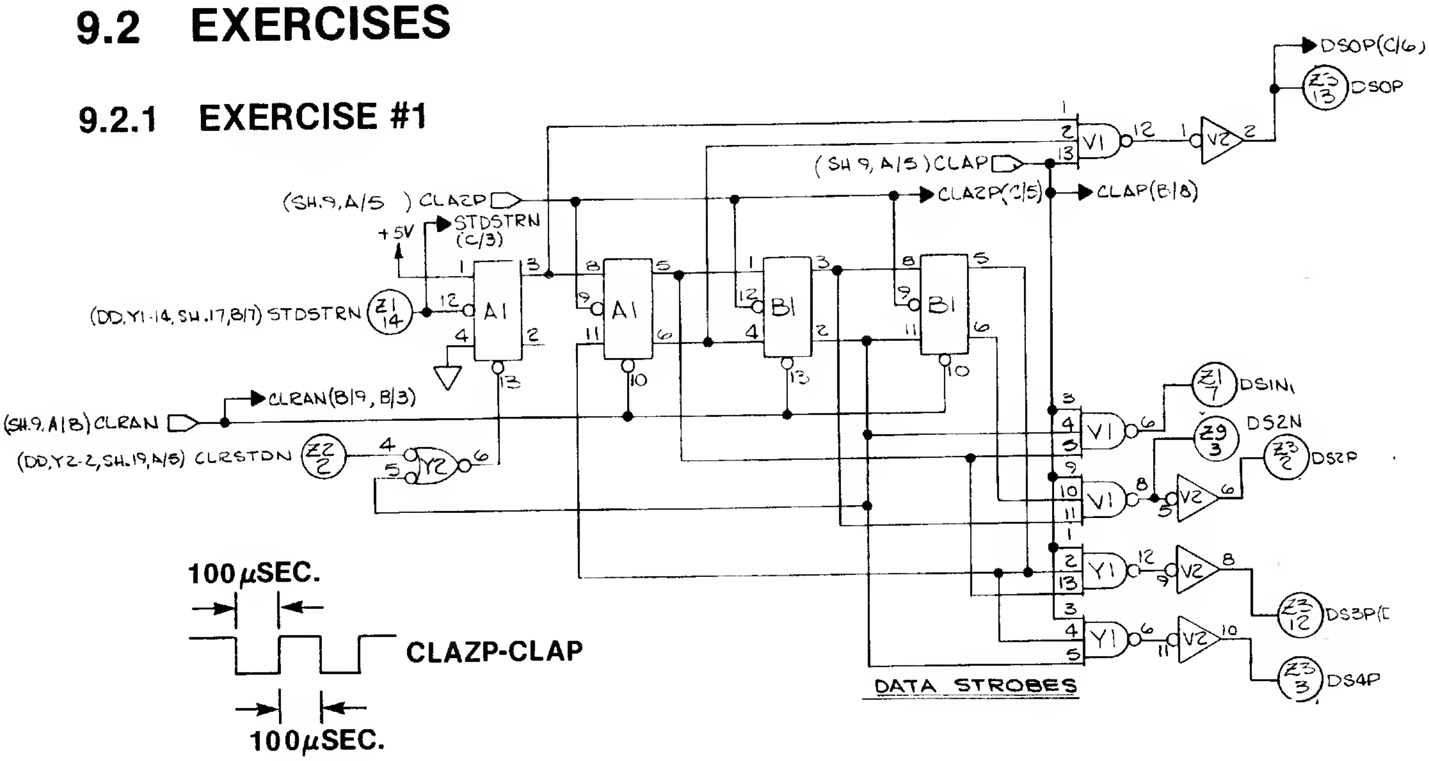


Figure 9.2 Timing Diagram

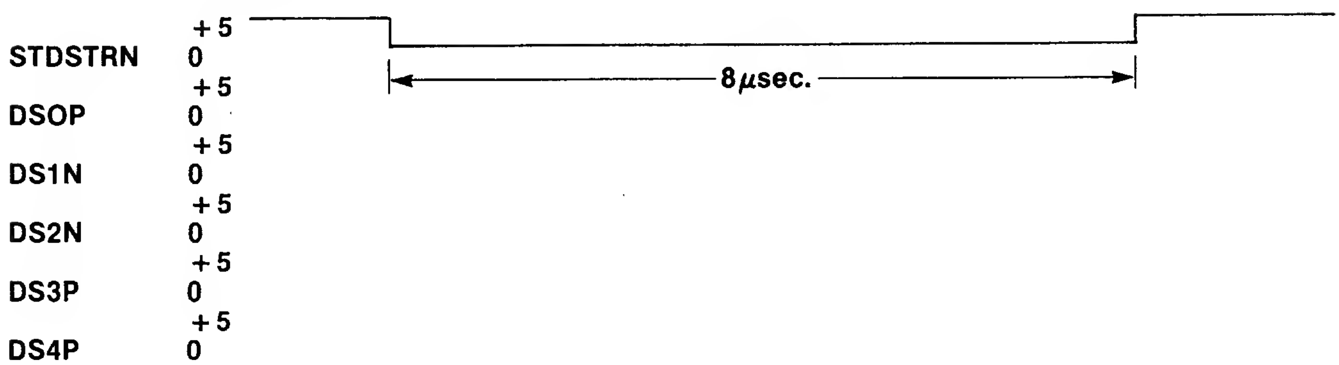
As illustrated in Figure 9.2, the expected results are as follows: **STDSTRN** will be a slightly delayed (up to 200 ns) at each transition, replica of **TSRCN**. **BLKSTTN** will be one 100 ns pulse because of the one-pulse network, H4, H2, Z5. Block P will rise at the fall of **BLKSTTN** and stay high until H2 flip-flop is cleared.

9.2 EXERCISES

9.2.1 EXERCISE #1



Plot out what you would expect to see for DSOP, DSIN, DS2N, DS3N, DS3P, DS4P.

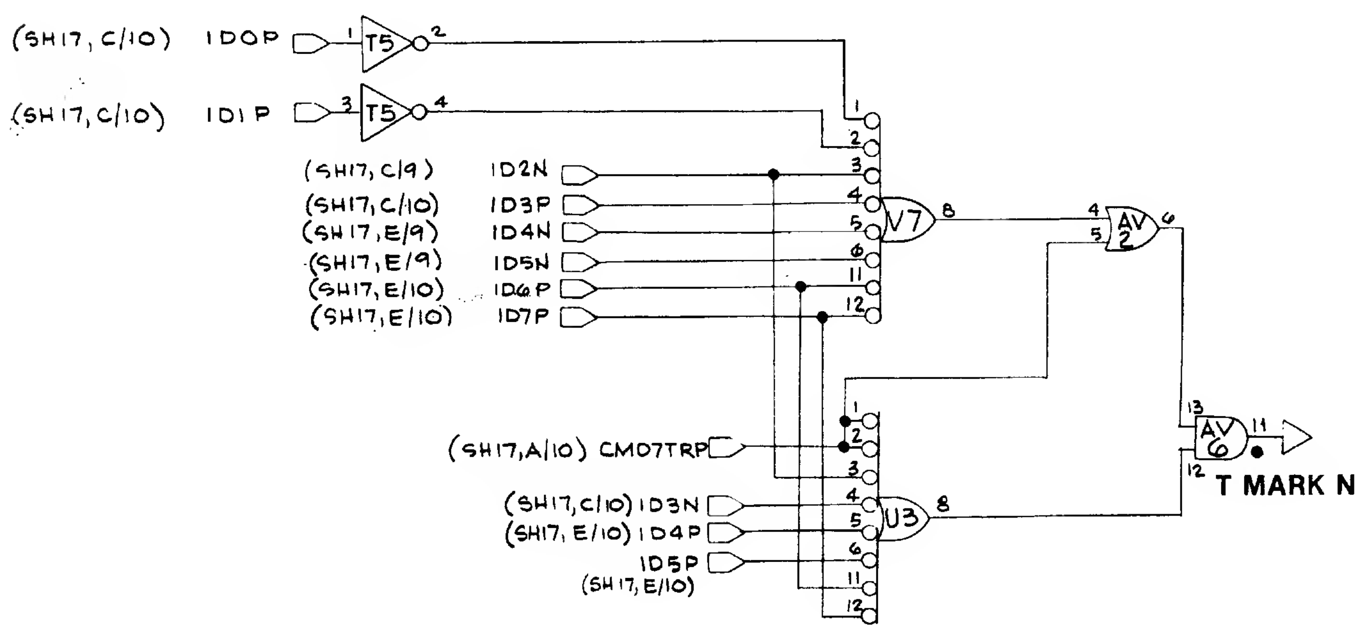


9.2.2 EXERCISE #2

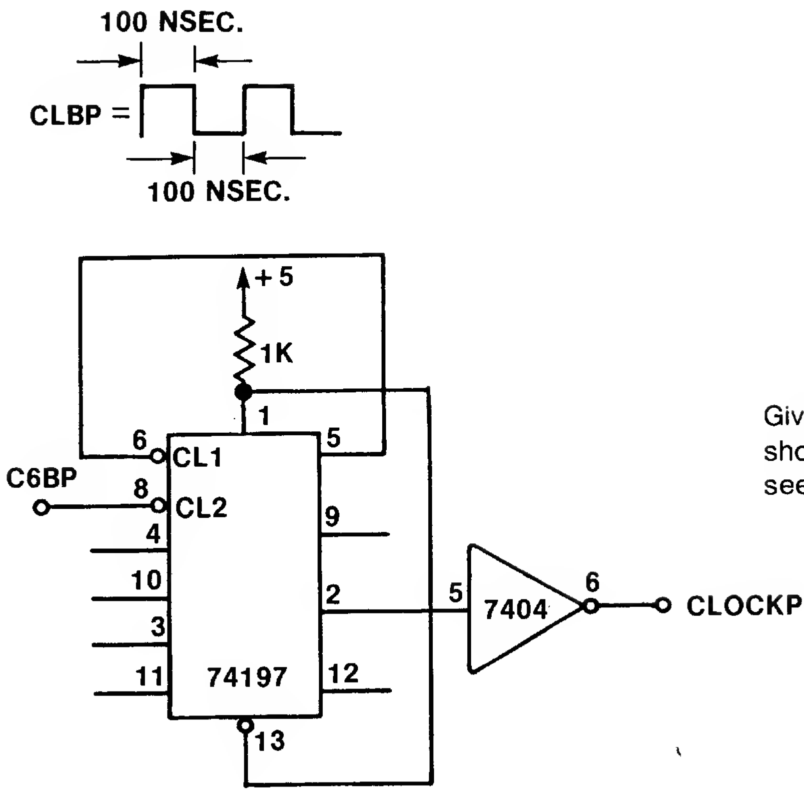
1. To what EBCDIC code, expressed in HEX, will AV6-11 respond when 7TRP is low?

2. To what BCD code, expressed in OCTAL, will AV6-11 respond when 7TRP is high?

In each case, what is the significance of the code? **HINT SEE FIGURE 8.1**



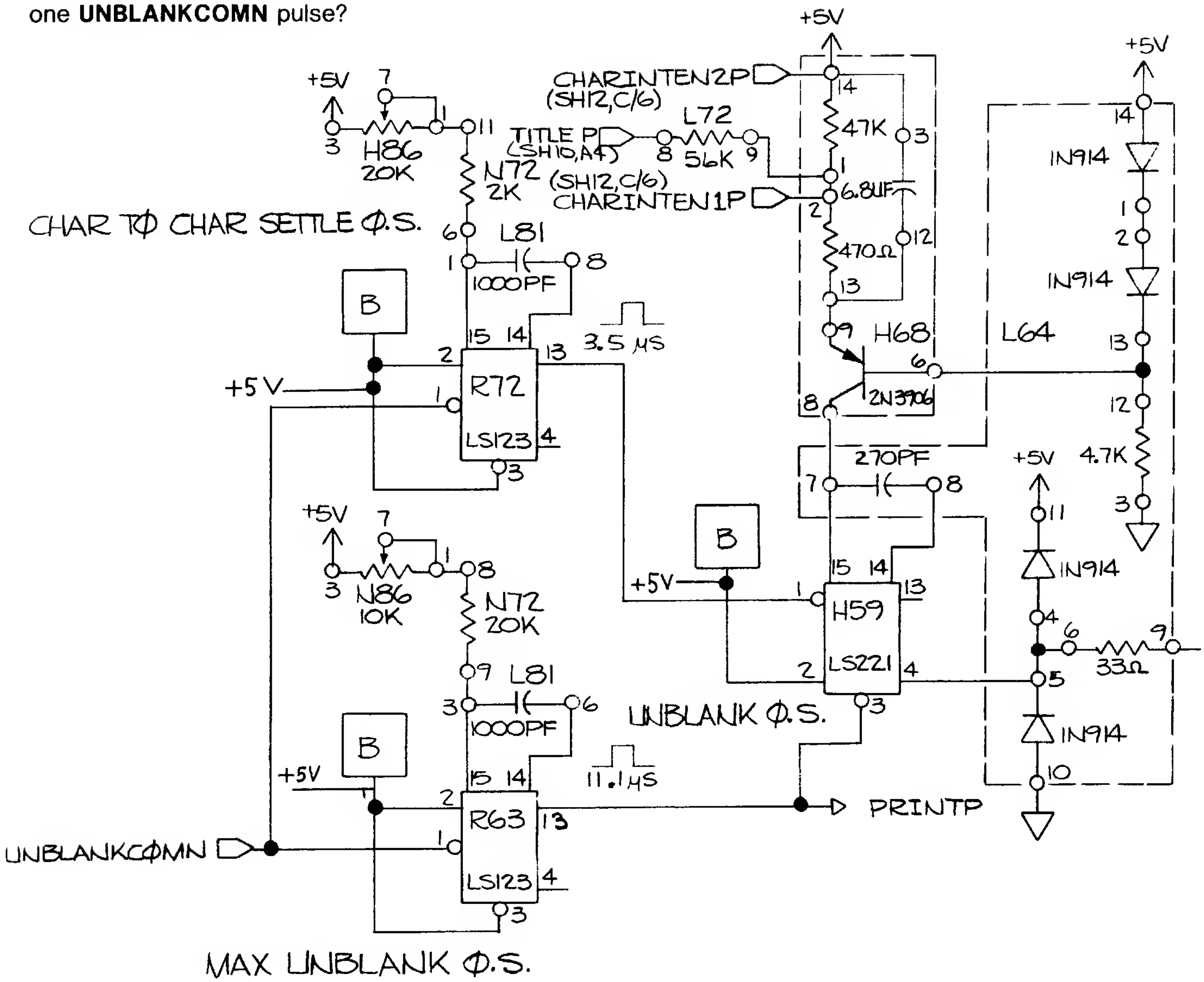
9.2.3 EXERCISE #3



Given the input clock signal (**CLBP**), show the output you would expect to see at "ClockP" output.

9.2.4 EXERCISE #4

What is the maximum possible time which H59 can stay set as a result of one **UNBLANKCOMN** pulse?



SECTION X

TUBE THEORY

10.1 INTRODUCTION

The principle image producing device in DatagraphiX COM recorders is a specialized display tube called a Charactron® Shaped Beam Tube (CSBT). The CSBT is a specialized cathode ray tube (CRT) utilizing unique techniques and controls to produce clear, bright alpha-numeric characters for recording onto microfilm.

Any discussion of the CSBT starts with a discussion of the simplest CRT design as found in television sets and oscilloscopes.

The principal parts of a simple CRT are: (1) A source of electrons, (2) A means to control the flow of those electrons, and (3) A means to convert the electron flow into a visible display.

A discussion of a simple CRT will serve to demonstrate these principle parts.

10.1.1 SOURCE OF ELECTRONS

The electron source is termed the cathode. This usually consists of a metal element coated with certain rare earth compounds and heated by a filament. It has been found that in a vacuum, free electrons are released from the compounds on the heated cathode. (See Figure 10.1.)

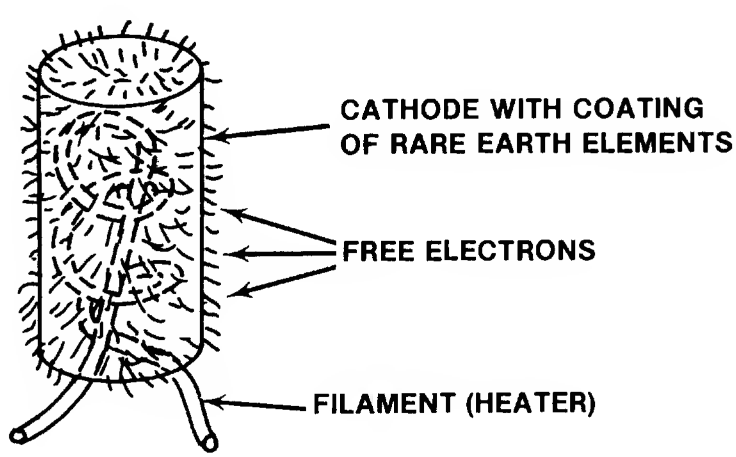


Figure 10.1 Cathode

Since electrons have a negative electrical charge, another element placed within the vacuum and having a positive potential (relative to the cathode) will attract these electrons, causing a stream of electrons to flow from the cathode to itself. This positive element is termed the anode. (See Figure 10.2.)

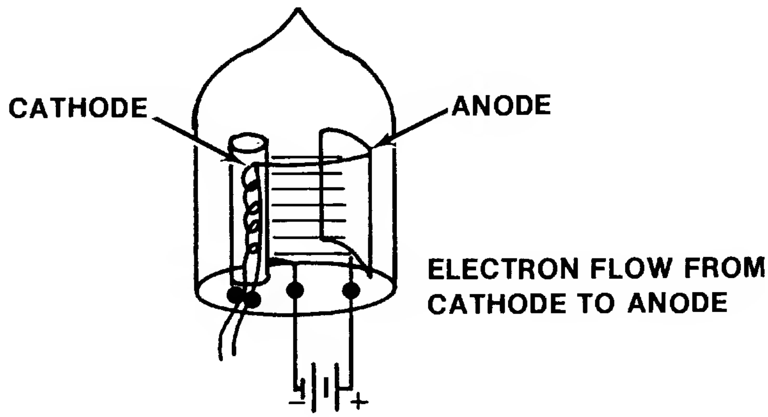


Figure 10.2 Electron Flow FRom Cathode to Anode

10.1.2 CONTROL

A wire grid placed between the cathode and the anode can be used to control this electron flow between the two elements. (See Figure 10.3.) If the grid is made to be of negative potential (relative to the cathode) the free electrons will not be attracted and the electron flow will stop. If made positive, the grid will attract electrons. However, due to the higher positive potential on it, most will continue on to the anode.

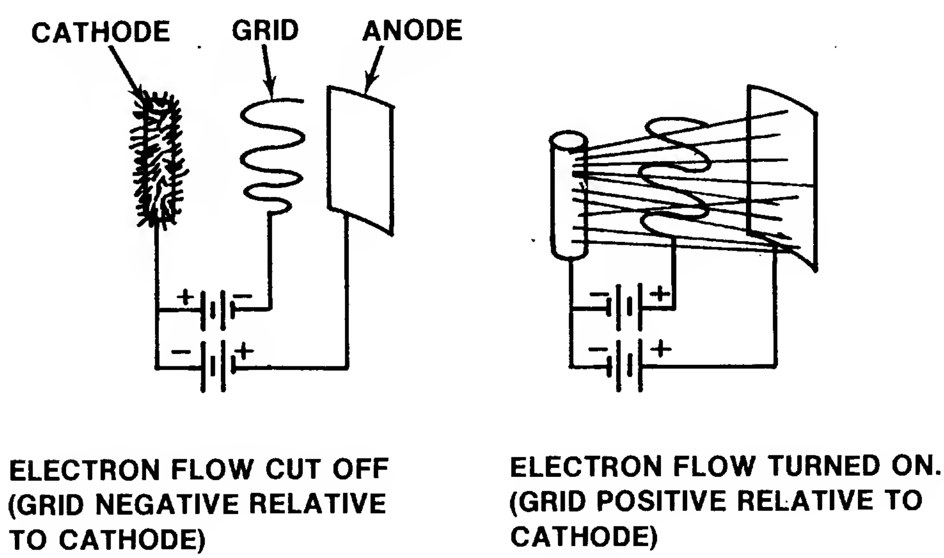


Figure 10.3 The Grid

10.1.3 VISIBLE DISPLAY

If the anode used is a phospher coated element, light will be emitted when the electrons strike it. A simple CRT using these principles is shown in Figure 10.4. In actuality, CRTs are more complex than this. More elements are used to form the electron flow into a narrow beam such that a single point on the anode or screen may be illuminated. Additionally, either by the use of electrostatic plates (plates or elements with voltage potential between them) within the vacuum tube or electromagnetic yokes outside the tube, the position of the beam on the tubes phosphor face may be controlled.

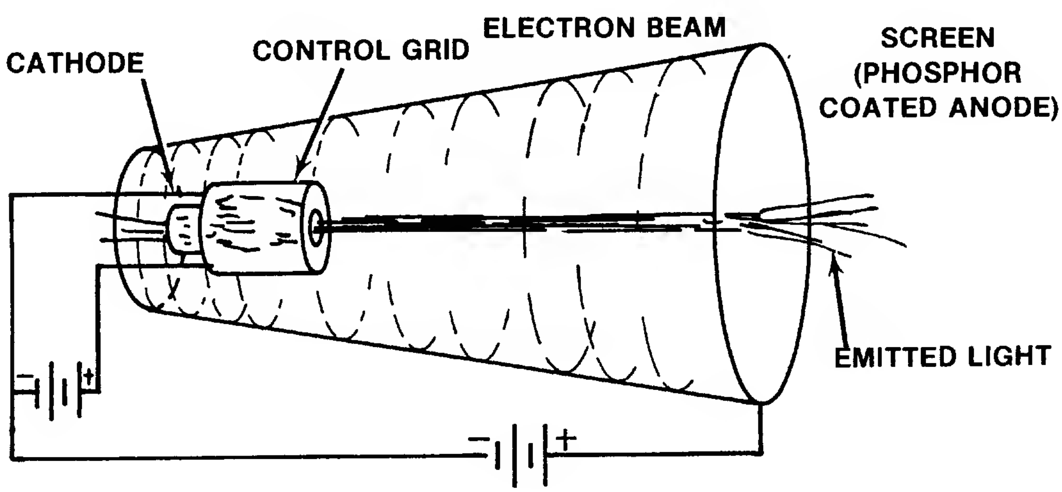


Figure 10.4 Simple CRT

Thus, the CRT has: (1) A source of an electron beam (the filament, cathode, control grid, and possibly other elements to control the size of the beam) commonly called the "gun"; (2) Control elements to determine where on the screen the êlectron beam strikes (commonly termed deflection circuits); and (3) A phosphor coated anode which converts the impinging electron beam into visible light (commonly called the screen).

To move from this simple CRt to the CSBT requires the addition of another element within the tube. As in the following illustration (Figure 10.5), we will introduce a metal stencil into the path of the electron beam. The beam, when striking the solid metal of the stencil, will be stopped. However, that part striking the open area will pass through and be extruded as a beam of electrons whose cross-section is the same shape as the stencil. When this "shaped-beam" strikes the phosphor screen, a lighted area of the same shape as the stencil will be produced.

The CSBT utilizes a metal stencil to shape an electron beam producing a sharp clear image of any character, number of special symbol for which a stencil can be made.

In actual practice, the stencil on a CSBT has a matrix of characters in it, only one of which is to be displayed at any given time. Thus, the problem of "selecting" which character to display.

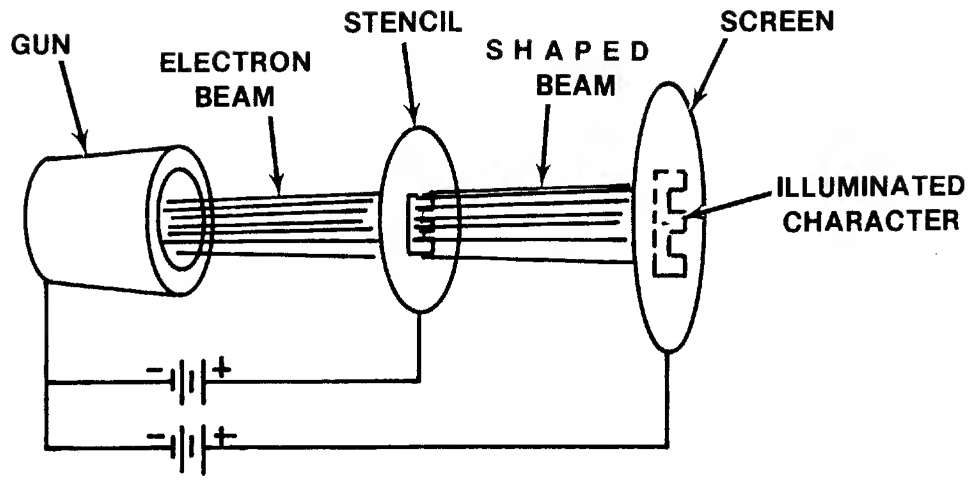


Figure 10.5 Shaped Beam Principle

10.2 SELECTION

To develop the principle of selection, we will discuss the CSBT Model C6B, the tube utilized in the DatagraphiX AutoCOM Microfilm Recorder.

This CSBT has a matrix of stencils in an arrangement 9 characters high and 14 characters wide, producing up to 126 different characters. The standard C6B matrix character layout is shown in Figure 10.6. The problem of selecting the character to be displayed involves: (1) Deflecting the beam from the central axis of the tube to the point in the matrix where that character stencil is located; (2) Returning the extruded beam to the central axis of the tube so that it may be sent on to be displayed on the tube face; and (3) Becaue the beam from the gun is larger than the character to be extruded, bits or chips from other stencils surrounding the desired character are also produced. These are undesirable and must be trimmed off before displaying the characters.

The problems of chips around the character is taken care of by another stencil called a trim aperture. This is a stencil with a single rectangular opening large enough to pass a character and small enough to trim off any "chips" surrounding that character.

From the simplified illustration, it can be seen that the angle the beam must be bent off the tube axis will be some value for any given character. The amount of bending required to turn the extruded beam back to the center axis is twice that original amount. Finally, the bending required to straighten the beam out on the tube axis is equal to the original angle. These three separate bending operations are referred to as selection, convergence, and reference, respectively.

Several methods are possible to produce the necessary bending of the electron beam. The C6B driving circuits utilize a magnetic yoke assembly called a unitized yoke. This is a specialized yoke wherein three separate sets of coils for selection, convergence, and reference functions are wound on a single form using a single wire. Therefore, a single current source will drive all three coils. The coils are wound and tuned such that the magnetic field produced by the convergence section is twice that of either the selection or reference sections, as bending of the beam is, for practical purposes, directly proportional to the intensity of the magnetic field.

Figure 10.6 Standard C6B Matrix Character Layout

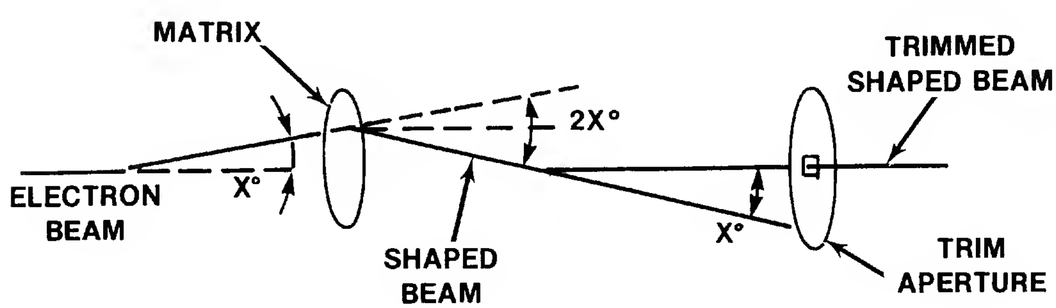


Figure 10.7 Selection Principles

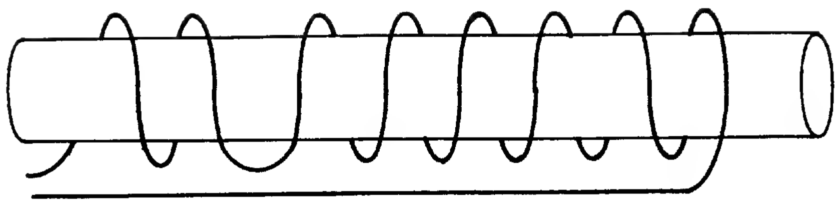


Figure 10.8 Uni-Yoke Principle

The actual process of "selection" involves: (1) Assigning each character in the matrix a unique value which describes its position in terms of vertical and horizontal location. (2) A system which can accept the description of the desired characters position and convert that description into appropriate voltages or currents to actually drive the yokes and accomplish the desired selection.

The description of each character's location in the matrix is expressed as a binary coded number. For example, the group character (‡) is location 00 (See Figure 10.9). Vertical location 0, horizontal location 0. The uppercase "A" is located on the matrix at Vertical 5, Horizontal 7. These vertical and horizontal values are represented as binary vertical (0101) and binary horizontal (0111) selection codes.

Figure 10.9 Matrix/Box Alignment Pattern

To convert these binary codes into the voltages and currents necessary to select the characters, several devices are used (See Figure 10.10).

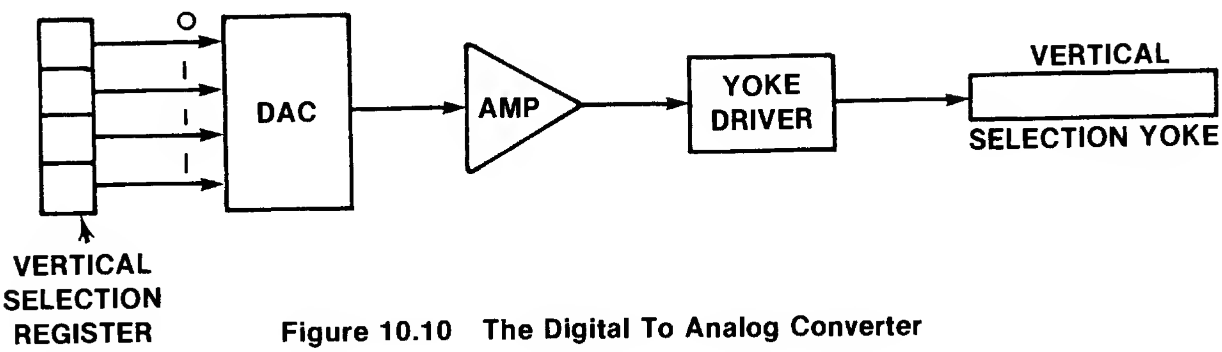


Figure 10.10 The Digital To Analog Converter

First, the selection code is inputted to a digital to analog converter (**DAC**). A digital to analog converter is a device which produces an analog output directly proportional to the digital value input to the device. For example, with a digital coded value of 0 (0000) the output will be zero volts. With a digital or binary 1 (0001), the output will be 1X volts. A binary coded 2 (0010) would give an output of 2X volts. Each additional change in digital input causes an equally tempered change in the output voltage. Thus, the DACs produce voltages proportionate to the digital selection codes. These voltages are amplified and applied to the selection yoke assembly where the current produces magnetic fields to bend the electron beam and select the desired characters.

10.3 DEFLECTION

After a character has been selected, the next requirement of the CSBT is to place that character in its appropriate position on the tube face. Because the characters are to be photographed, the tube face is a flat surface. This reduces the cost and complexity of the necessary optical system.

As previously discussed, magnetic yokes may be used to direct an electron beam to various points on the tubes surface. The flat tube face, however, presents some problems insofar as uniform placement of these characters is concerned.

As previously discussed, the amount of bending of an electron beam is essentially directly proportional to the magnetic field acting on it and the field is essentially directly proportional to the current in the yoke. Thus, the angle of bending is directly proportional to the current. Double the current - double the angle.

Referring to Figure 10.11, if the tube face were curved such that its surface was always equidistant from the center of deflection, the distance the beam deflects on that curved face would be directly proportional to the current in the yoke. That is, double current, double displacement - a linear relationship. With a flat face tube, however, the surface of the tube is not equidistant from the center of deflection. Thus, while the angle of deflection is still directly proportional to current, the distance deflected is **not**, but increases the further from the center of the tube face the beam is deflected. This causes a non-linear function as the beam is moved away from the center of the tube face. Each additional equal increment of current results in a larger and larger increment of deflection. This non-linearity results in a distortion pattern in flat-faced tubes known as pincushioning (see Figure 10.12).

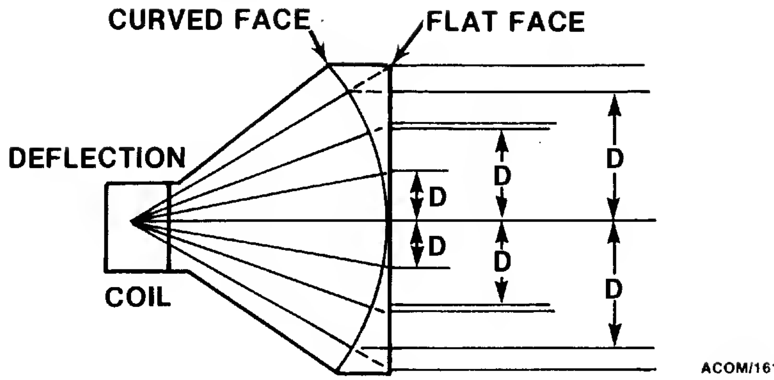


Figure 10.11 Flat Tube Face Geometric Distortion Diagram

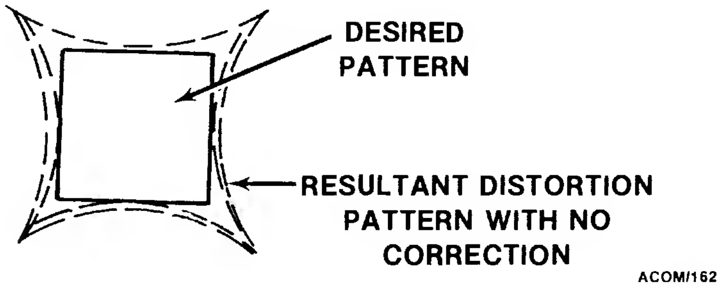


Figure 10.12 Pincushioning Diagram

Deflection circuits for C6B start with DACs which convert a digital description of the desired position on the tube face into voltage levels in a manner similar to the DACs used in selection. Next, the voltages are fed into a linearity correction circuit (Figure 10.13). The function of the linearity circuit is to progressively reduce the size of voltage and consequently current steps as deflection moves away from the center of the tube face. When properly adjusted, this reduction will result in the actual deflection on the tube face being linear which is to say in uniformly sized increments.

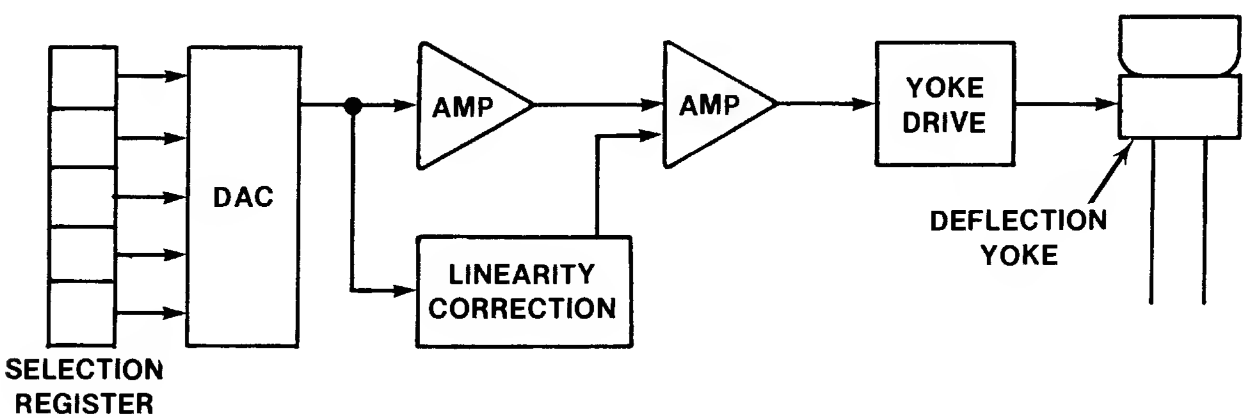


Figure 10.13 Linearity Correction Circuit

Because the amount of change increases in a non-linear manner as deflection moves away from the center of the tube, so the necessary correction signal is not a linear function. Near the center of the tube face, little, if any, correction is required. Toward the edges, a great deal of correction is required.

10.4 ASTIGMATISM

Another phenomena related to deflection in CRTs is astigmatism. This is distortion of a characters shape due to deflection away from the center of the tube face. This can be very aptly illustrated by considering a flashlight beam shining on a wall. Shining directly at the wall, the beam is round, however, as the beam is deflected so that it strikes the wall at an angle, the shape becomes elliptical. The same effect distorts characters deflected away from the tube face center. The most obvious example is the box character (□) appears tilted at the corners of the display ( ).

Astigmatism correction is accomplished using coils which are oriented at a 45° angle to the selection and deflection yokes. The way in which this yoke is wound allows correction of this astigmatism tilt of the characters. The correction signal is derived from deflection signals as the distortion is related to the distance vertically and horizontally that the character is deflected from the center of the tube face.

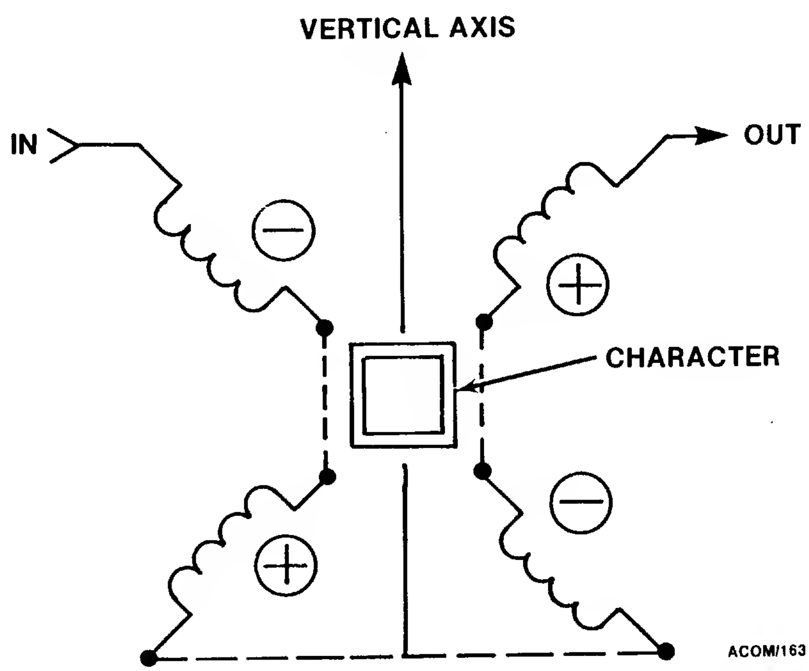


Figure 10.14 Astigmatism Correction

SECTION XI

MAGNETIC TAPE

11.1 THE HISTORY OF MAGNETIC RECORDING

11.1.1 EARLY EFFORTS

Although the use of magnetic recording in data processing is relatively new, the basic concept of recording information via a magnetic medium has been a reality for more than half a century.

This concept was originally explored by Valdemar Poulsen, a Danish telephone engineer. Poulsen, often referred to as the "Danish Edison", constructed an operational magnetic recording device in 1893. He improved upon this machine, which he called the "Telegraphone", and received the first patent issued for a magnetic recording device in 1898. Though crude by modern standards, his device received the Grand Prix at the 1900 Paris Exposition.

Poulsen's machine used a steel piano wire as the storage medium with information encoded crosswise on the wire; however, a difficulty in the use of wire was its tendency to twist and bend as it passed the reproducing head, thereby causing the crosswise recording to go out of alignment. One other serious fault with the machine was the lack of amplification. This resulted in a very weak signal strength even when the quality of recording was acceptable.

The new technique showed great promise in the field of sound recording and reproduction, but due to the lack of sufficient amplification, development toward its full potential did not occur until after the invention of the triode tube by Lee DeForest in 1907.

From their inception until the later 1920s, magnetic recording devices were used primarily in laboratories where experiments resulted in changes and minor improvements to Poulsen's machine. Most of these experiments were conducted in Europe, principally in Germany. The recording medium used in these experiments was either steel wire or a steel tape.

Wire dictating machines were manufactured in Germany and met with some success. A company was formed in the United States to market the Telegraphone, but American businessmen were reluctant to accept the device and the company soon folded.

At this point in the development stages, the need for a more suitable recording medium was apparent. About 1920, the possibility of using a tape coated with a powdered magnetic material was suggested.

In 1927, a German inventor, Karl Pfleumer, began searching for a material to replace steel wire as a recording medium. He explored the feasibility of using a paper or plastic tape coated with a powdered magnetic material. Two German firms, AEG Company (Allgemeine Elektrizitats Gesellschaft) and

BASF (Badishe Anilin - und Soda - FabrikA.G.) collaborated on Pfleumer's work and produced the first practical tape with a magnetic particle coating. The base of this tape was paper with an iron oxide or metallic particle coating. There is some question as to the type of material first used as a coating.

As could be expected, this tape was far from perfect. The recording surface of the tape was comparable to a rough grade of sandpaper, and the adhesive material was of such poor quality that when the tape was run on the recording machine, the coating would separate from the base material in a fine spray and literally cloud the air.

About 1935, a recorder using this paper tape was exhibited and marketed. This recorder, the "Magneto-phone", was more readily accepted, although it lacked the mechanical qualities of Poulsen's Telegraphone. The deciding factor for its success was the tape which reduced the operating cost from dollars-per-recording minute, as with steel tape, to pennies-per-recording minute.

Magnetic recording activity in the United States was revived when, in 1937, Bell Laboratories developed a high quality recorder, the "Mirrophone", and Brush Development Company produced its "Sound Mirror" recorder. Both of these recorders used a steel tape as a recording medium and the "Sound Mirror" had a recording time of approximately one minute on a loop of tape.

With the world on the brink of war, the sharing of technological advances, including magnetic recording, was halted. Both the U.S. and Germany could foresee the requirement for devices capable of quickly and accurately recording information. The Germans naturally took advantage of their past accomplishments and pursued the development of coated tape while the United States concentrated on steel wire and steel tape. In the late 1930's, the Japanese were also exploring the field of magnetic recording.

11.1.2 WAR EFFORTS

As in other areas, World War II added impetus to the experiments being conducted and rapid developments were forthcoming. The Germans, by 1939, had developed a relatively good plastic tape and also a number of good recording machines, including a device with a rotating head and one with a tape speed of 30 inches per second.

In the United States, Brush was experimenting with a paper tape and also a coated wire for recording. Other companies were becoming active in the field and around 1943, Webcor was manufacturing wire recorders for the Navy. Late in 1944, Minnesota Mining and Manufacturing Company (3M) undertook experiments in an attempt to develop a recording tape using a ferro-magnetic powder as a coating.

Near the end of the war, an improved version of the German Mangetophone was captured intact and, at the conclusion of the war, the American recording industry reaped the benefits of German research and ingenuity.

From this time, steel wire and steel tape as a recording medium, was replaced with plastic-base tape. Magnetic tape recording became a household term as numerous manufacturers produced home recorders as well as recorders for industrial and business applications.

11.1.3 COMPUTER TAPE

With the advent of computers and their ultimate wide-spread use in everyday life, there arose a need for a device capable of rapidly exchanging information with computers. The device should also have the capability of retaining the large amount of data generated by these computers.

About 1947, the use of magnetic recording devices in computer systems was initiated. Since this time, the development and improvement of magnetic recording devices and magnetic tape has progressed hand in hand with the development and improvement of computers.

The speed of modern data processing computers is such that extensive files of data are needed for economical use of the machine's capability. The day has come when the slow process of manually feeding information into a computer is too time consuming to be tolerated.

The speed of the automatic computer system is derived primarily from the stored-program concept wherein both the program and the information to be operated upon are contained within the Memory Section. Memory is very expensive, and the economy of a system is impaired by including a memory larger than absolutely necessary. An auxiliary memory, freeing main memory for computation programs and data, is desirable. An auxiliary memory is needed which has the ability to place in main memory the program and information to be used immediately, to store that which will eventually be needed, and to return to storage that which has been used. A solution to this need was magnetic tape.

Magnetic tape's greatest advantage is the high transfer rate of data between the tape and the computer in both directions. With its use, the necessary memory space can be held at a minimum. A scheme is to reserve an area of memory for the program and an area for the information to be operated upon. As the instructions are being read and executed in one portion of memory, another portion can be prepared with new instructions and information stored in the newly-prepared area. The contents of the old area can be stored on tape.

11.2 CONSTRUCTION OF MAGNETIC TAPE

The construction concept of magnetic tape is quite simple: particles of iron oxide or other materials are spread on and made to adhere to a thin ribbon of plastic which is wound on a reel. There are three basic ingredients that are used to make magnetic tape: (1) Oxide coating, (2) Binder, and (3) Backing or base material.

11.2.1 OXIDE COATING

The magnetic layer consisting of oxide particles held in a binder that is applied to the base film is called the oxide coating. The ferromagnetic material is usually gamma-ferric oxide (Fe_2O_3) in the form of acicular (needle-shaped) particles less than one micron in length (1/1000 of a millimeter or 0.000039 inches). It is very important that the oxide coating is both uniform and smooth. For computer tapes, this means that the coating thickness must be .00045 inches along the entire 2400 feet length. If the oxide particles are not uniform in size, the surface of the tape will be rough, making the tape more abrasive. This could cause reduced head life and greater oxide contamination. Non-uniformity in thickness also lends itself to variations in average peak signal output.

11.2.2 BINDER

The substance usually composed of organic resins, used to bond the oxide particles to the base material is called a binder. The actual composition of the binder is proprietary information to the magnetic tape manufacturer; therefore, little is known about this component except that it is probably the most important part of the manufacturing process. The binder must be flexible and tough without having the oxide chip or flake off. If the binder's consistency is sticky, the individual tape layers will adhere to each other when wound on a reel.

11.2.3 BASE MATERIAL OR BACKING

The most common type of backing in use today for computer tape is Mylar, the DuPont trade name for Polyethylene terephthalate. The chief advantages of this polyester over other base film lies in its humidity stability, its solvent resistance, and its mechanical strength.

Cellulose acetate, which preceded Mylar, is relatively strong but not as stable as Mylar. Cupping is an undesirable feature of cellulose acetate which will render a computer tape completely useless.

Other backing materials are in use today such as Tenzar, a 3-M Product; Polyvinyl Chloride, and Luvitherm, both BASF (Badische Anilin - & Soda - Fabrik A.G.) products. These plastics have yet to play a large part in the construction of magnetic tapes.

11.3 THEORY OF MAGNETISM

11.3.1 CLASSES OF MAGNETS

Magnets are classified as being natural or artificial according to the manner in which they are formed. The ancient Greeks knew that certain stones found in the town of Magnesia in Asia Minor had the property of attracting bits of iron. These stones were called magnetite and, as we know today, this is an iron ore possessing magnetic qualities.

Although useful in the days of the acient Greeks, magnetite, a **natural** magnet, has only historical value today. Stronger and more efficient magnets can be produced by artificial means.

An **artificial** magnet can be formed by placing a bar of iron or steel in a coil of insulated wire and passing a current through the coil as shown in Figure 11.1. As the current passes through the coil, magnetic poles are formed as indicated by "N" representing the North Pole and "S" the South Pole. The bar is said to be magnetized.

The molecular theory of magnetism is illustrated in Figures 11.2 and 11.3. Figure 11.2 shows a piece of unmagnetized iron where each molecule is considered to be a tiny magnetic. These molecular magnets are arranged in a random manner. The magnetism of each of the molecules is neutralized by adjacent molecules and no external magnetic effect is produced. When a magnetizing force is applied to the iron bar, the molecules align themselves so all North Poles (N) point in one direction and all South Poles (S) going in the other direction as shown in Figure 11.3.

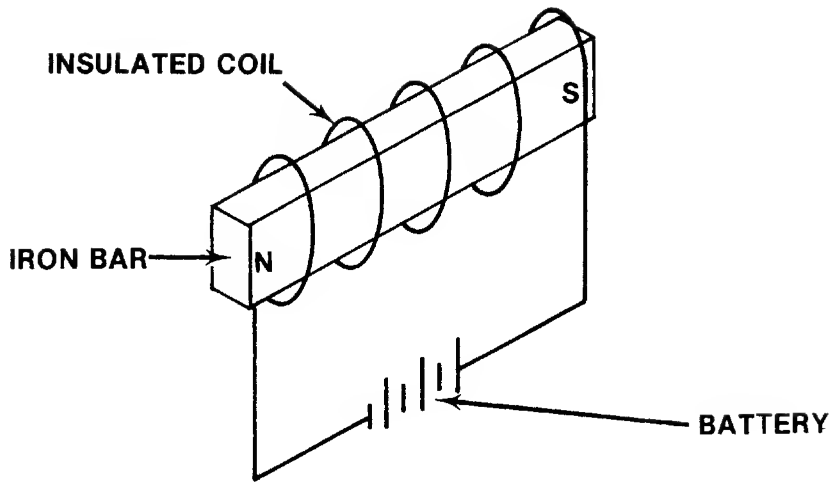


Figure 11.1 Forming An Artificial Magnet

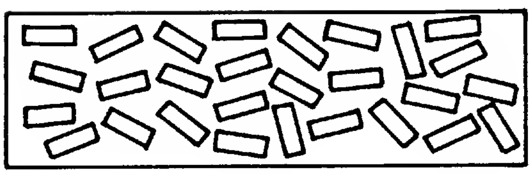


Figure 11.2 Unmagnetized Bar

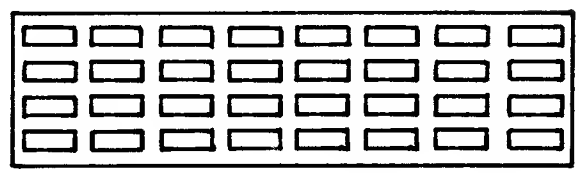


Figure 11.3 Magnetized Bar

11.3.2 TYPES OF ARTIFICIAL MAGNETS

An artificial magnet may be either of two types - permanent, or temporary - depending on its ability to retain magnetic strength after the magnetizing force has been removed. Hardened steel and certain alloys are relatively difficult to magnetize and are said to have a low permeability because the magnetic lines of force do not easily permeate, or distribute themselves readily through the steel. These materials, however, do retain a large part of their magnetic strength and are said to be permanent. This ability of a material to retain its magnetic strength is referred to as the retentivity of the material.

Soft iron has a high permeability and is called a temporary magnet due to the fact that it can retain only a small amount of its magnetic strength when the magnetizing force is removed.

Figure 11.4 illustrates a bar magnet and some of the facts that are known about magnets.

11.3.3 MAGNETIC PRINCIPLES

All magnets have two poles - a North Pole (N) and a South Pole (S). A magnetic field exists around the bar magnet. This field consists of imaginary lines along which a magnetic force acts. These lines

emerge from the North Pole of the magnet, and enter the South Pole, returning to the North Pole through the magnet itself and forming closed loops. The entire quantity of magnetic lines surrounding a magnet is called magnetif flux while the number of lines per unit area is called flux density.

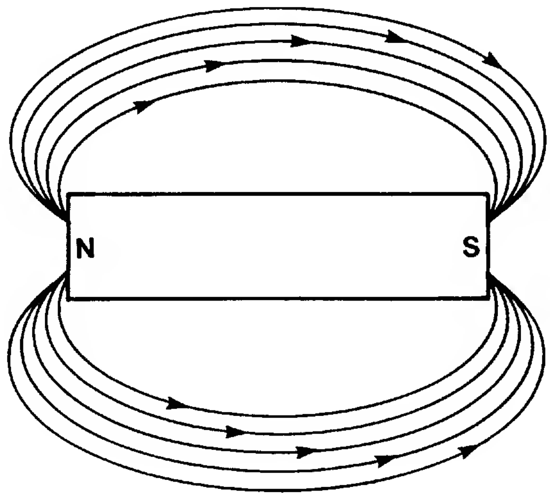


Figure 11.4 Magnetic Lines of Force

If a bar magnet is bent to form a loop without the ends touching (as shown in Figure 11.5), a magnet will be formed having a magnetic field that is of shorter length and greater concentration than the bar magnet.

One characteristic of the imaginary lines in a magnetic field is that they tend to take the path of least reluctance (magnetic resistance). In other words, they pass through the material that has the greater permeability. Air offers more reluctance to the lines of force than does iron or steel.

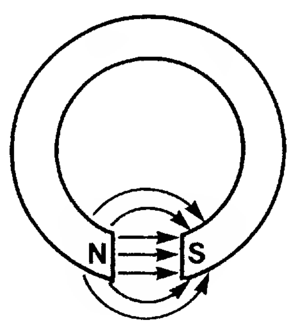


Figure 11.5 "Horseshoe" Magnet Showing Concentration of Magnetic Field

If a piece of iron is brought into proximity with the gap of the horseshow magnet, as shown in Figure 11.6, the lines of force will tend to bend so as to pass through the iron. The piece of iron will become magnetized by the imaginary lines flowing through it. This characteristic of magnetism, refered to as induction, is utilized in the process of magnetic recording.

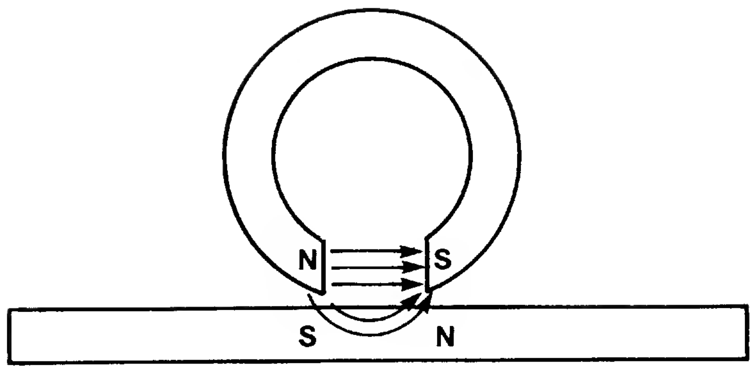


Figure 11.6 Lines of Force Inducing Magnetism

11.3.4 THE ELECTROMAGNET

If an electric current flows through a piece of wire, a magnetic field is built up around the current-carrying conductor. Referring again to Figure 11.1, when a coil of wire is placed around a piece of iron and a current flows through the coil, the magnetic field of the coil magnetizes the iron bar. A device of this type is called an electromagnet. If the direction of current flow is reversed, the polarity of the magnetized core will reverse.

The core of the electromagnet can be in the shape of the horseshoe magnet of Figure 11.7. An electromagnet of this configuration is basically the type of device used as a "write" head in a magnetic tape recorder.

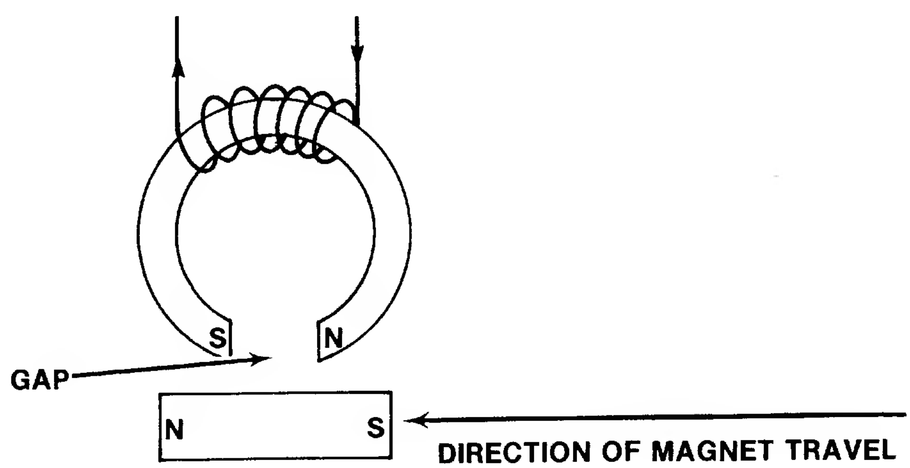


Figure 11.7 Inducing Current in a Coil

In Figure 11.7, an electromagnet is shown with another magnet being passed close to the gap. As the magnet passes, its lines of force will flow through the core of the electromagnet and a current will be induced in the coil. This is basically the idea behind "reading" information from a magnetic tape.

11.4 BASICS OF MAGNETIC RECORDING

11.4.1 SURFACE RECORDING WITH ALTERNATING CURRENTS

One fundamental method of recording on tape involves the magnetization of minute areas on the surface of a highly retentive magnetic material. In order to reproduce the recorded information, the magnetic state of the material is "read" back by using the retained or residual flux to induce voltages in the read circuit. This method, commonly called surface recording, is used to record information on magnetic tapes.

Magnetic surface recording is based on the interaction between a material, such as magnetic tape, and a magnetic head (transducer) in relative motion.

11.4.1.1 Writing - First we will explore surface recording; the process of "writing" on a magnetic tape. In order to accomplish this, there must be a basic understanding of the construction of the recording, or "write" head.

It was pointed out in the section on magnetism, that a horseshoe magnet has an air gap through which a magnetic field or magnetic flux is present. This magnetic field is comprised of invisible lines of force that emanate from the North Pole of the magnet and enter the South Pole, making a closed loop.

The recording, or "write" head used in magnetic tape recording is basically an electromagnet similar to the horseshoe magnet discussed eariler.

Figure 11.8 is a simplified drawing of a recording head having no current flowing in the coil and, consequently, no magnetic field. In order to generate a magnetic field, current must flow in the coil, as shown in Figure 11.9. If current is flowing as indicated by the arrows, an electromagnet is formed with North and South Poles and lines of force as indicated. In Figure 11.10, the direction of current flow has been reversed. Note that the poles of the electromagnet reverse with the resultant reversal in the direction of the lines of force.

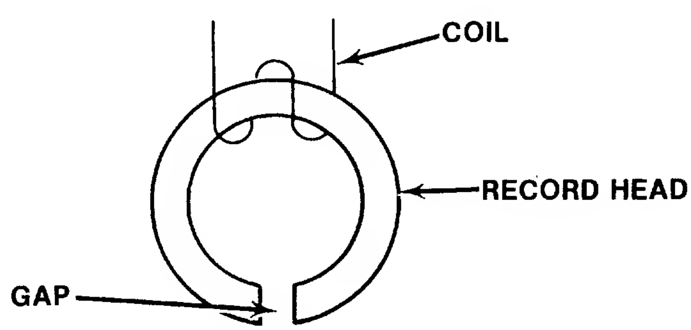


Figure 11.8 No Current Through Coil

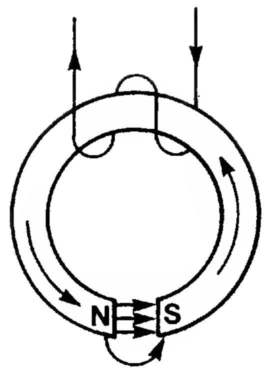


Figure 11.9 Current Through Coil

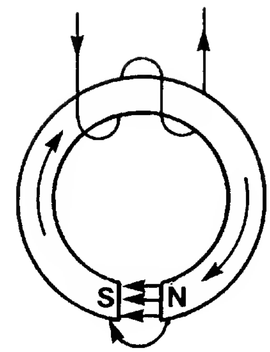


Figure 11.10 Current Reversed

Based upon the foregoing principles, the events which occur when a magnetic tape is brought into contact with the head can be more readily understood.

The fact has already been pointed out that magnetic tape is constructed of a plastic base coated with a material that has the capability of being magnetized and of retaining that state of magnetization for an indefinite period of time.

Figure 11.11 shows the recording head with no current in the coil, therefore, a magnetic field is not present and no change takes place on the surface of the magnetic tape.

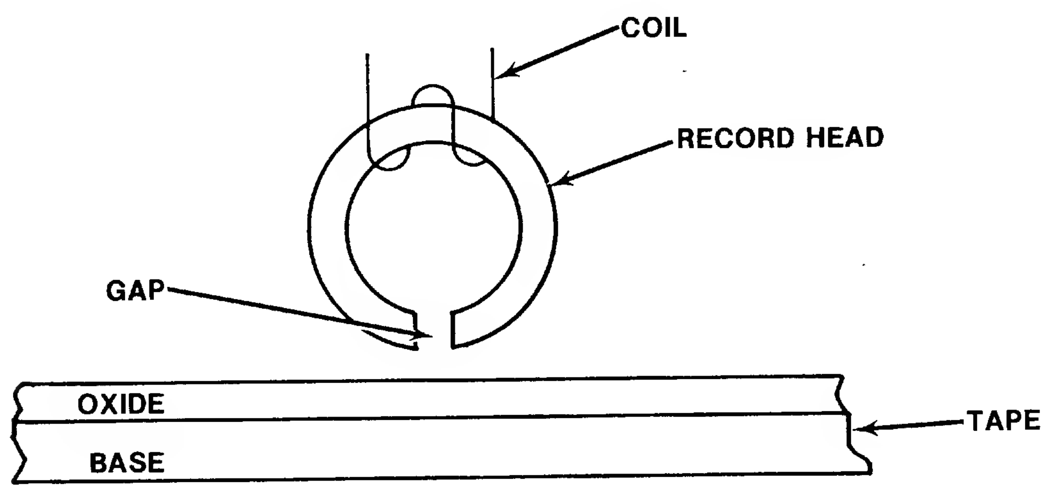


Figure 11.11 No Current Through Coil on Recording Head

In Figure 11.12, the head is shown with current flow and the resulting magnetic field. The magnetic field passes through the surface of the tape and changes the magnetic polarity of a small area.

The current direction is reversed in Figure 11.13, and as shown, a different condition exists on the surface of the tape.

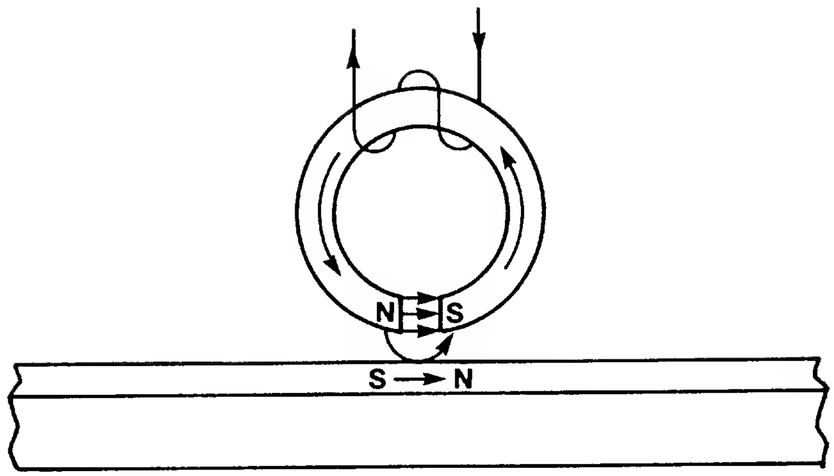


Figure 11.12 Current Through Coil on Recording Head

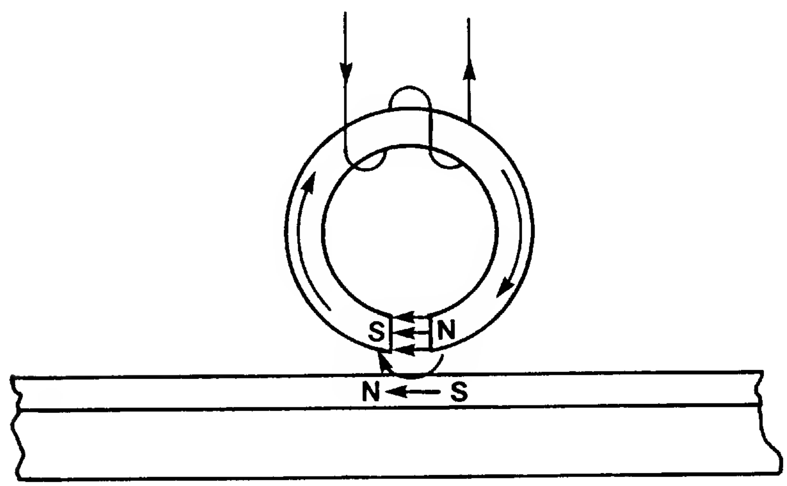


Figure 11.13 Current Reversed Through Coil on Recording Head

It was previously pointed out that surface recording is dependent on relative motion between the recording head and the tape. Figure 11.14 shows the relationship of a fixed recording head with magnetic tape moving in the direction shown. The illustration also shows one cycle of an alternating current and the resulting current flow through the coil. Note that the current flow through the coil reverses with a change from positive to negative direction and the polarity of the recorded information on the tape also reverses.

We have examined only one cycle in the process of recording on tape. This could be continued for any number of cycles with each one establishing two definite areas of magnetized tape of opposite polarity.

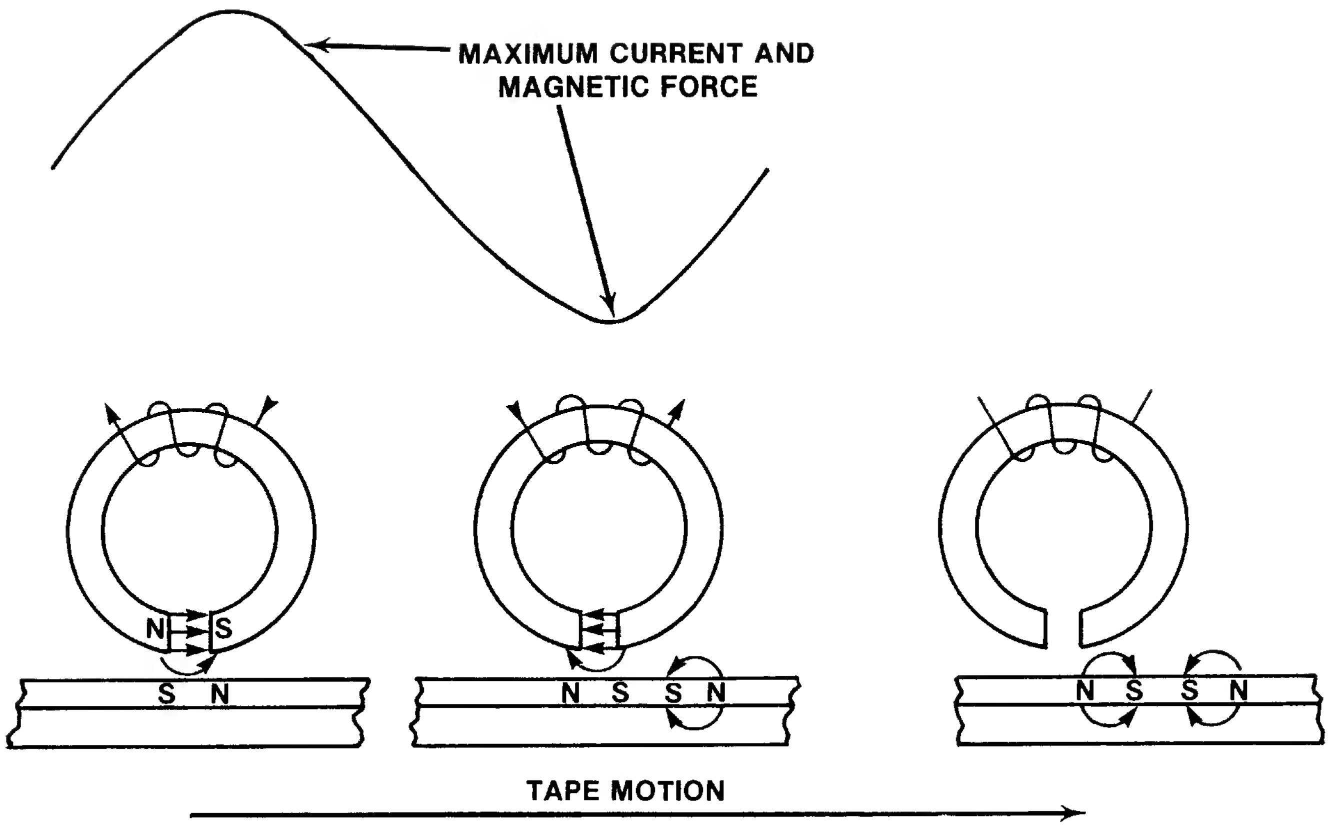


Figure 11.14 Recording (Wire Operation)

11.4.1.2 Reading - In the "Read" or reproduce operation, a previously recorded tape will move into the vicinity of the read head gap. It should be pointed out that the "read" head is quite similar in construction to the "write" head.

Figure 11.15 shows a stationary head with the tape being moved in a given direction. In this illustration, we are interested in a changing magnetic field associated with one alternation. As the tape passes under the read head, the changing polarity of the recorded information on tape induces a current in the read head coil. Note that a current is produced in the coil only when the magnetic field on the tape changes. When the information is read from tape, it in no way alters the magnetic state of the tape so that a recorded tape can be read an indefinite number of times.

11.4.2 SURFACE RECORDING DIGITAL INFORMATION

In the preceding discussion, we have been concerned with an alternating current inducing a change in the magnetic state of the tape. In recording digital information, as encountered with digital computers, we are concerned with recording information represented by pulses which represent the binary states of "1" and "0".

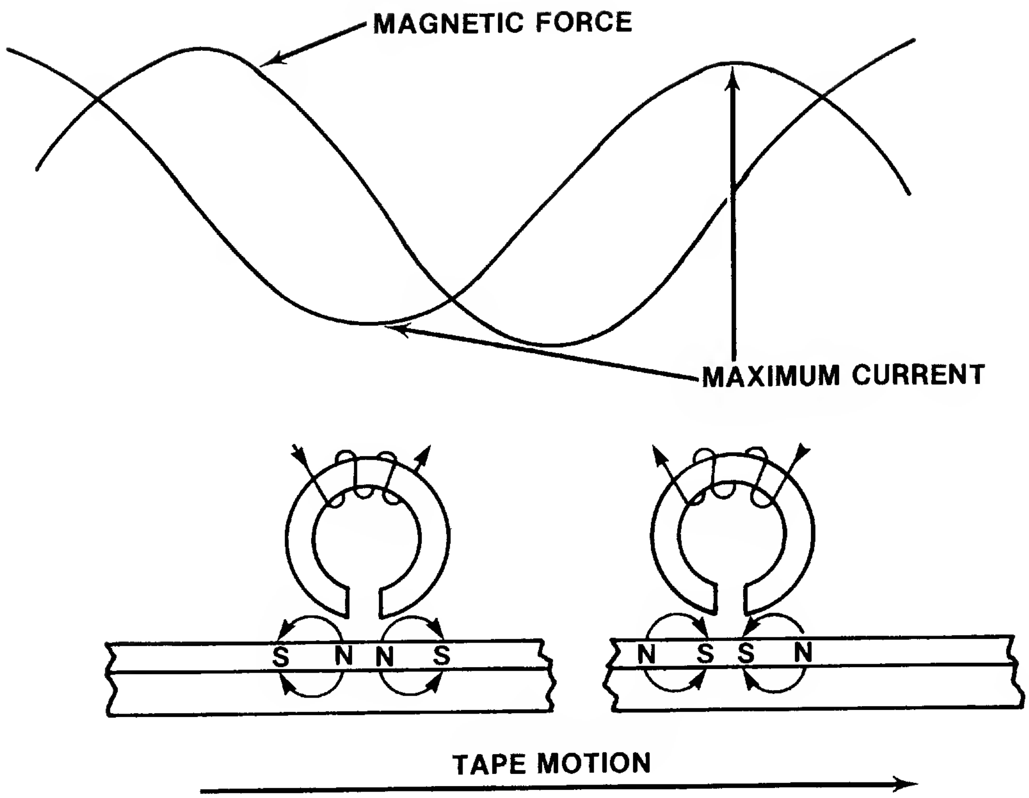


Figure 11.15 Reproducing (Read Operation)

There are numerous schemes for recording digital information, but we will consider for this discussion, a common easy-to-understand scheme - the Non-Return-To-Zero, Change on Ones (NRZI) method). This particular method is also designated Non-Return-To-Zero, Indiscrete (NRZI).

The illustration in Figure 11.16 shows the "write" current applied to the coil of the write head, the flux configuration of the magnetized particles on tape, and the signal developed as the tape is read.

Note that a change in the write current occurs only when a "1" is to be recorded whereas during the period when "0"s are recorded, the write current remains at the same level. A change in the flux pattern on tape occurs only when the write current changes (a "1" is to be recorded). A change in the flux pattern on tape does not occur if the write current does not change ("0"s are recorded).

During a read operation, a read signal is produced only when a change in the flux pattern on tape is encountered, signifying that a "1" has been recorded. When a change in the flux pattern is not present, zeros are read.

The material presented in the foregoing is intended to be only a brief description of basic theory of tape recording and one of the recording schemes necessary for a more thorough understanding of tape certification.

In Figure 11.16, only one track is considered. As you will see in subsequent discussions, multiple tracks are recorded simultaneously across the width of the ½ inch tape. Most commonly, nine tracks of data are recorded. Less common now but still popular is seven track recording.

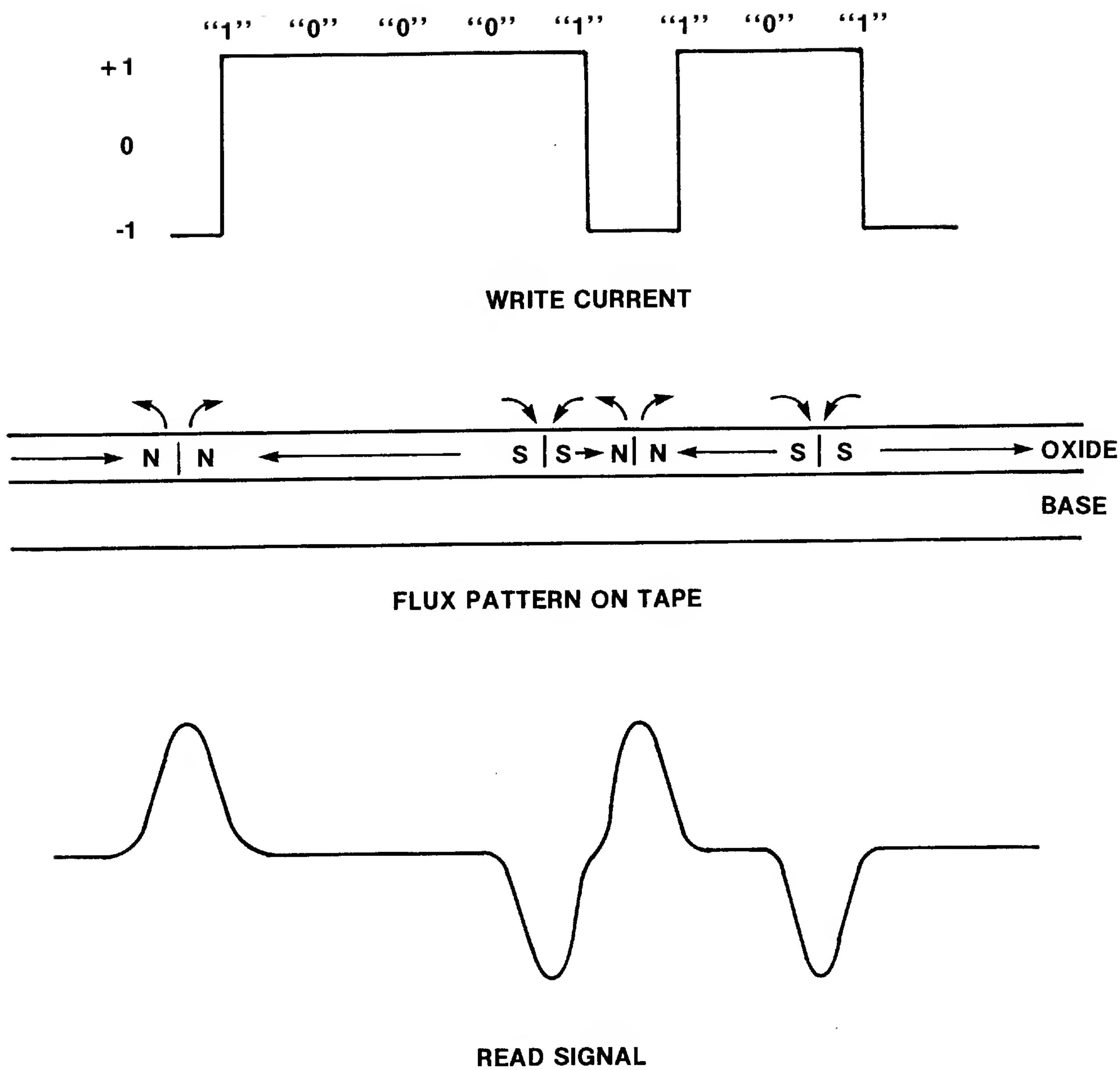


Figure 11.16 Non-Return-To-Zero, Change on Ones

11.5 TAPE PHYSICAL COMPOSITION AND LAYOUT

Digital recording tape is composed of a mylar plastic base which has one side covered with an oxide or ferrous oxide coating of uniform thickness and density.

Tape size is ½ inch wide (0.498 ± 0.002 inches). Tape thickness is 1-½ mil (0.0015 inch). Standard lengths per reel are:

8 inch diameter reel = 1,200 feet of 1-½ mil. tape
10.5 inch diameter reel = 2,400 feet of 1-½ mil. tape

Tape is wound onto the tape reel as shown in Figure 11.17. The hub end is placed next to the core of the reel and wound clockwise around the core. The "reference" edge of a tape is defined as the edge next to the usually clear plastic side of the reel (the front side). The oxide side is wound facing the core of the reel. The job end is not attached to the hub or core of the reel. The rim end is the end left free after winding the tape onto the reel. With oxide side down and rim end to the right, the reference edge will be the edge closest to the observer. The reference edge is used as a starting point for many measurements, such as, track placement and identification, and marker locations.

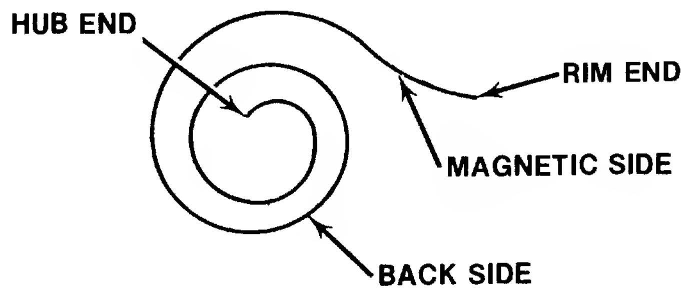


Figure 11.17 How Tape Is Wound On The Tape Reel

The reels have a standard inside hub diameter of 3.690 inches. The inside ᵕımension between reel sides is 0.55 inches. This allows a nominal clearance between tape edges and reel sides. Each reel of tape should have two reflective markers; one for beginning of tape (BOT) and one for end of tape (EOT). Locations vary slightly depending upon the recording format to be used. Specifications are shown in Figure 11.18, NRZI Tape Markers; and Figure 11.19, P.E. Tape Markers.

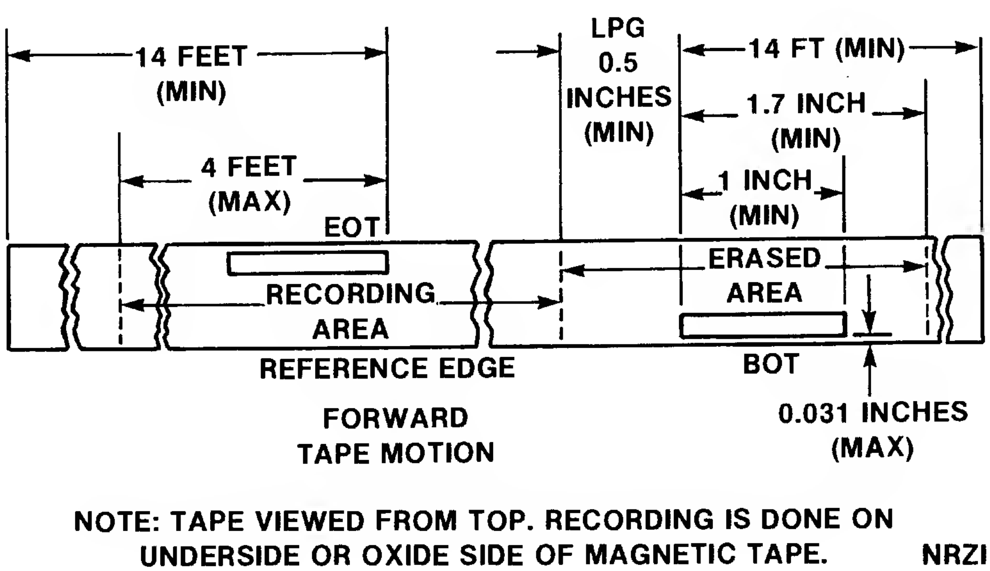


Figure 11.18 NRZI Tape Markers

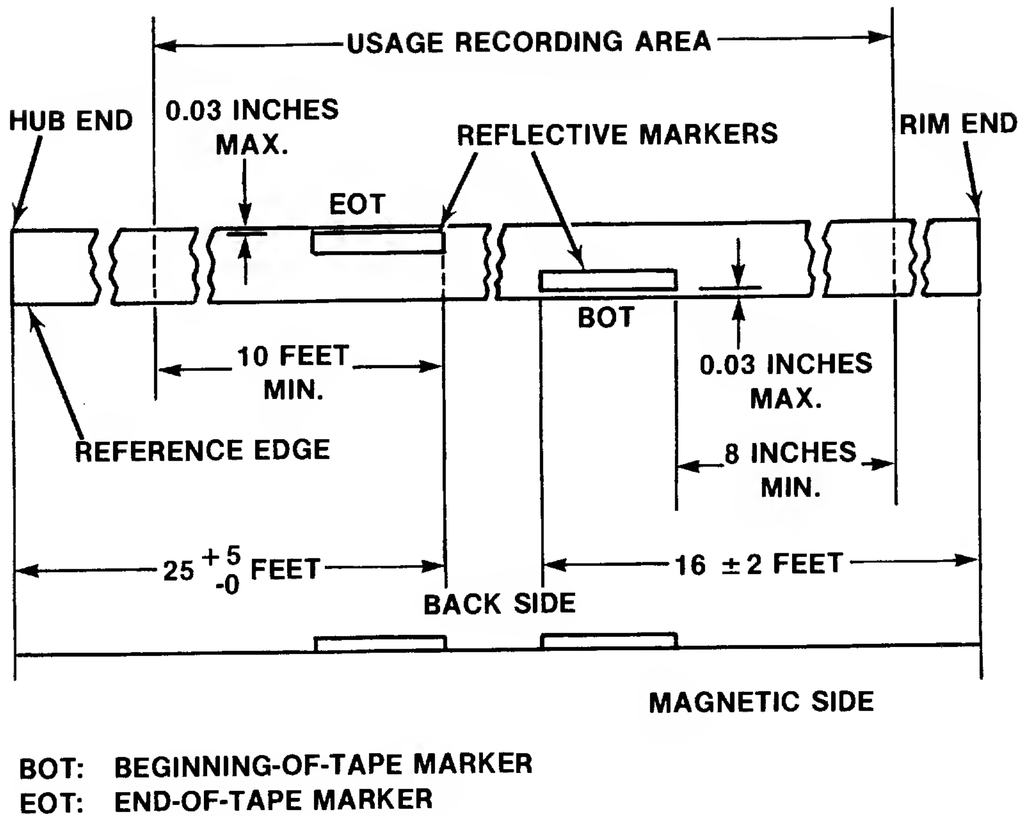


Figure 11.19 P. E. Tape Markers

The markers are silver reflective foil 1.1 inches ±0.2 inches in length and 0.19 ± 0.02 inches in width and 0.0008 inches maximum thickness.

Markers are usually self-adhesive and are applied to the base material side of the tape. They should not protrude beyond the edge of the magnetic tape, nor wrinkle or distort the tape.

The Beginning of Tape (BOT) marker is sensed by tape transports and used to define the "load point" or starting point of recording. The End of Tape (EOT) marker, when sensed, is made available to the tape interface to allow termination of recording within 4 to 10 feet past the EOT. EOT has no function in read modes.

Markers should be replaced whenever they are not reflective. This can be caused by scratches or dulling from wear or abrasion. Care must be taken not to damage the oxide area around the markers as this portion of the tape is considered part of the usable recording area.

11.5.1 TRACK LAYOUT

Digital tapes are recorded and read on a multiple track format - by convention, either 7 or 9 tracks. Each track is produced longitudinally (along the length of the tape) by an individual recording head gap (see Figure 11.20). The multiple gaps are arranged into a single assembly. The standard dimensions

for head and track layouts for 7 and 9 track recordings are shown in Figure 11.21. Note that the width of the write gaps or tracks are wider than the read gaps. This allows a margin of tolerance in tape tracking when reading the recorded data.

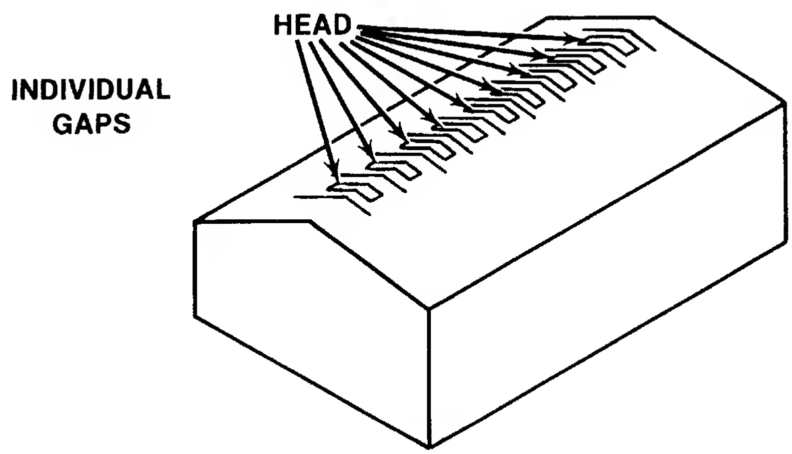


Figure 11.20 Tape Head Construction

In tape head manufacturing, the taps must be placed perpendicular to the reference edge of the tape. Due to manufacturing tolerances, the gap placement cannot, economically, be perfect. In high quality heads, the tolerances are typically a variation in the area of 50 to 75 microinches total between all tracks. This deviation within the vertical column is termed gap scatter (see Figure 11.22).

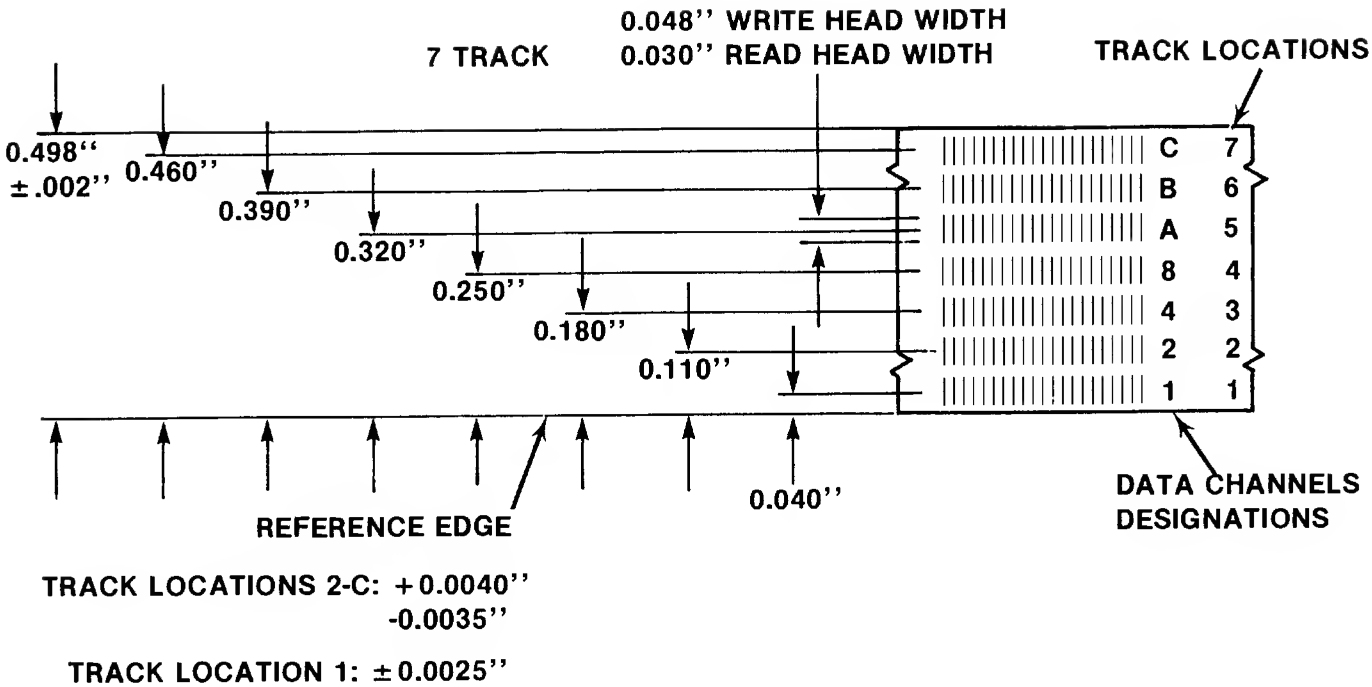
Due to the longitudinal displacement, gap scatter creates a situation wherein tracks will see flux changes on the tape at different times. This phenomena is called skew.

Another source of skew is mechanical alignment of the head relative to the tape path. That is deviation of the effective centerline of the head from true perpendicularity to the tape path as in Figure 11.23. This is usually termed azimuthal skew.

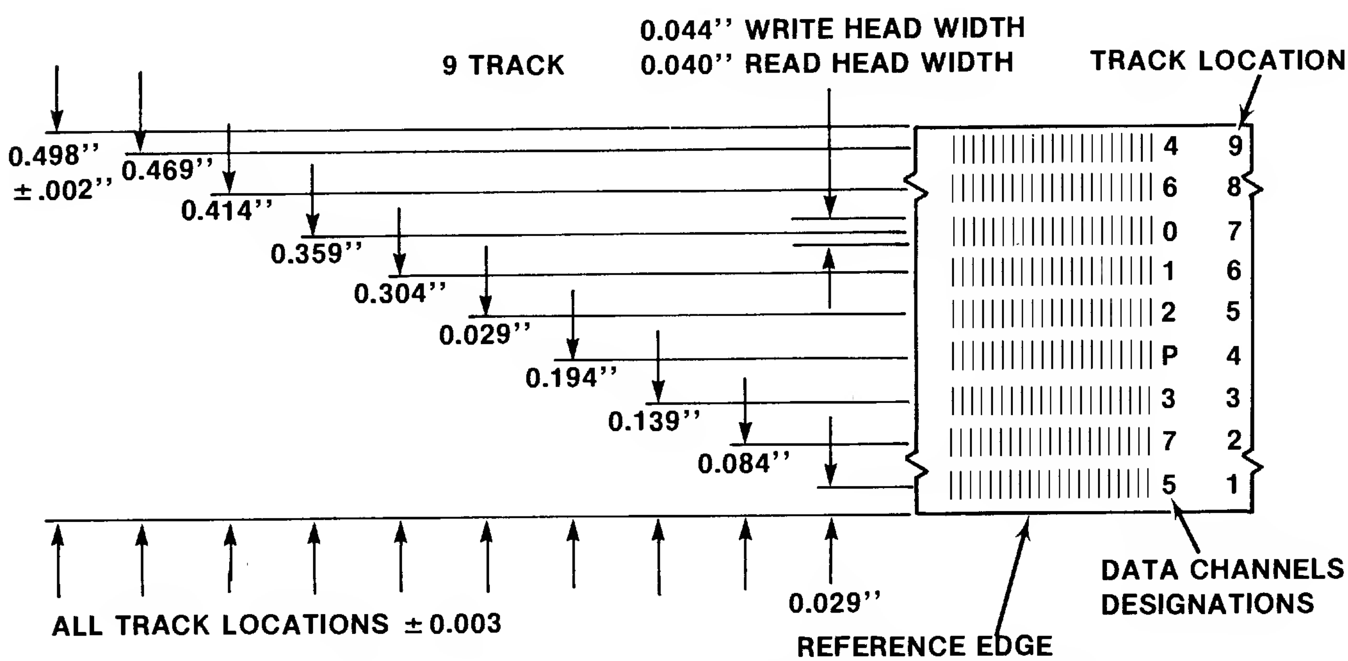
These sources of skew or time displacement between tracks must be compensated for in the read electronics in order to reproduce the data originally recorded simultaneously on the multiple tracks. The skew due to mechanical tolerances in head manufacture and mechanical alignment is called static skew.

In an ideal situation, tape moves across the heads in a smooth, straight and continuous manner. In actual practice, this is not the case and, as tape passes across the heads, some undesired movements take place. The effects due to undesirable tape movement are classed as dynamic skew and may be termed transverse, lateral and longitudinal, which define the axis over which the movement takes place.

Transverse movement is defined as side to side motion of the tape such that centers of the tracks on tape shift relative to the centers of the head gaps.



TRACK LOCATIONS AND SPACING, 7-TRACK SYSTEM



TRACK LOCATIONS AND SPACING, 9-TRACK SYSTEM

ACOM/164

Figure 11.21 Track Data

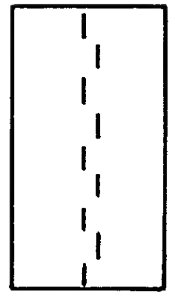


Figure 11.22 Gap Scatter

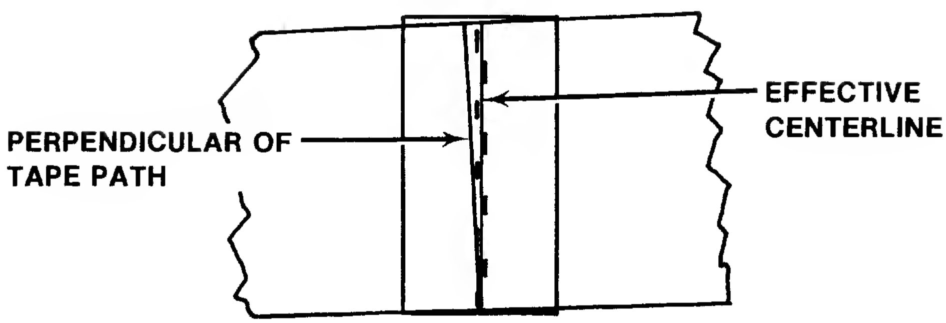


Figure 11.23 Azimuthal Skew

Lateral movement or skewing is characterized by one edge of the tape slightly leading the other in time. This dynamic condition, which is constantly changing due to tape motion, is similar to azimuthal skew.

Longitudinal movement error involves irregular tape speed. In practice, tape speed across the head is irregular due to power variations, eccentric rotary elements and tape friction effects. This causes the time between bits detected to fluctuate.

Lateral, short term longitudinal, and transverse movements are called dynamic skew or jitter (see Figure 11.24). These effects can be minimized by careful and accurate alignment of the entire tape path, from supply reel through all tape guides, buffering, read head, capstan and take-up reel. Long term longitudinal motion (speed) variations are termed flutter and as such, measured and included in the specifications of tape transports.

Verification and adjustment of head alignment is done using a master (skew) alignment tape. A master skew tape is a precisely controlled tape written with a single gap full width head. Skew verification is made by observing the two outside track signals while the transport moves the alignment tape across the head. The two flux transitions displayed must occur simultaneously. If alignment is required to align the gaps, either the tape head or the tape path guides must be repositioned. When both outside tracks are reading the same flux transition at the same time, the gap centerline is perpendicular to tape motion. Tolerance permissible is typically half of the allowable gap scatter, or 25 to 37.5 microinches.

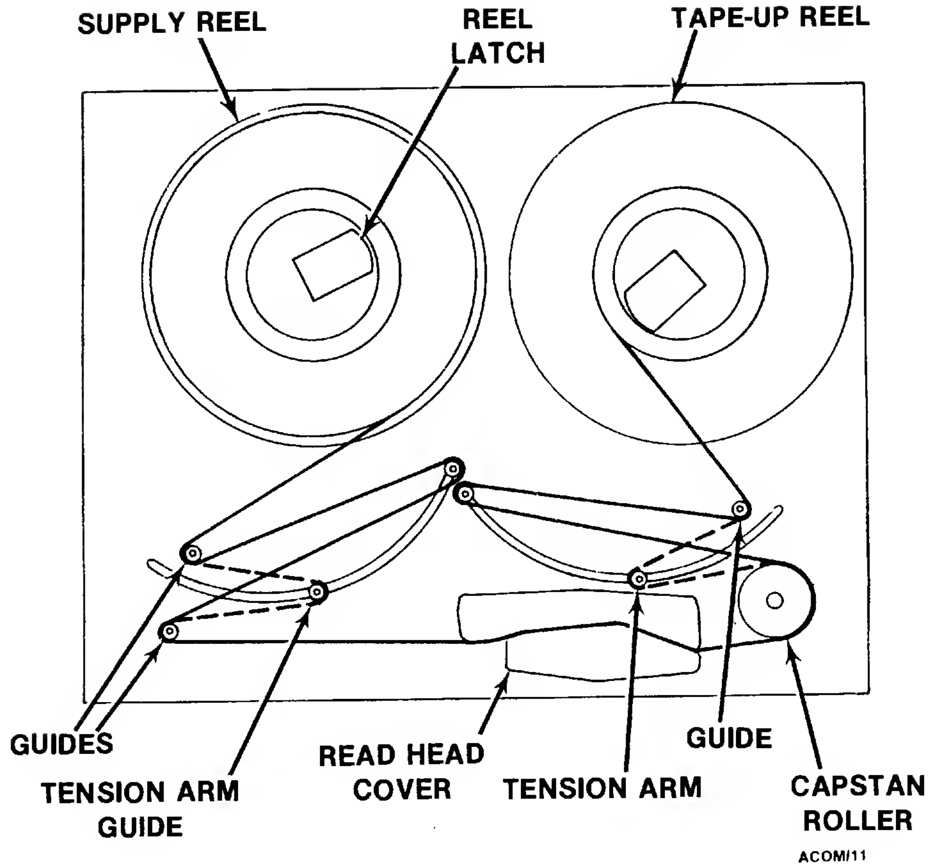


Figure 11.24 Tape Drive Dynamic Skew

Microseconds of error observed can be converted to microinches with the following formula:

Tape speed x microsecond displacement = microinches

Example: Two outside tracks are displaying the same flux transition with a time displacement of 1.0 microsecond. Assuming the tape unit is operating at 75 ips (inches per second), the displacement in microinches can be calculated:

75 ips x 0.000001 sec = 0.000075 inches = 75 microinches

With a tolerance of 25 to 37.5 microinches allowable, this error of 1.0 microsecond would need to be adjusted to 0.5 microsecond or less to fall within acceptable limits (see Figure 11.25).

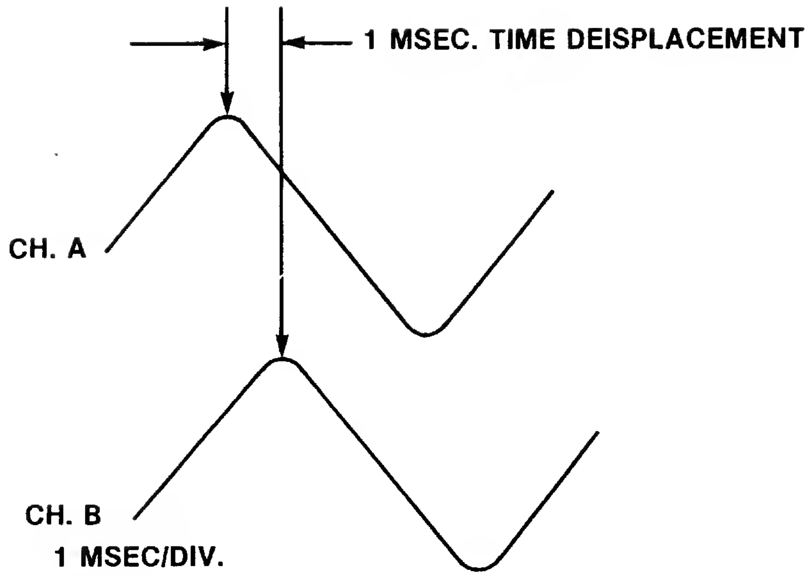


Figure 11.25 Flux Transition Tolerance

11.6 RECORDING METHODS AND FORMATS

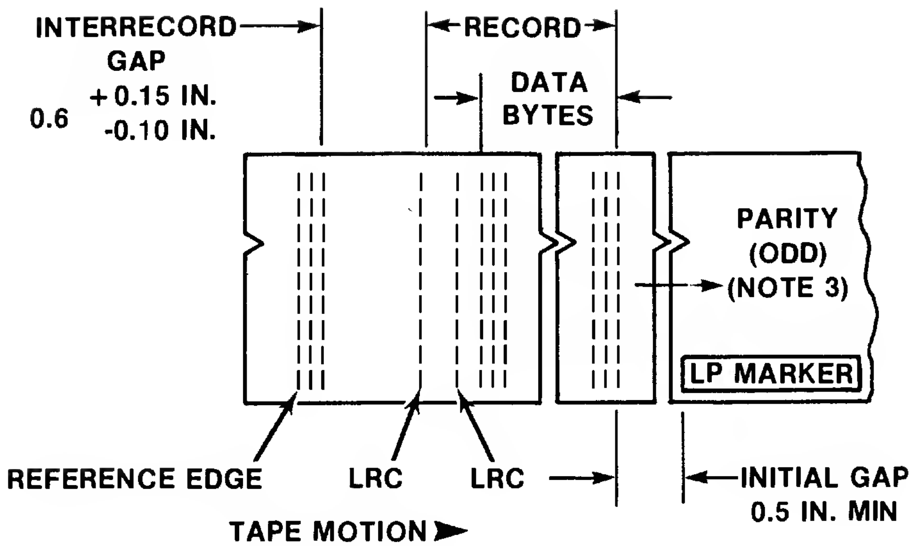
11.6.1 NRZI RECORDING

As discussed in Section 11.4.2, NRZI recording utilizes a change in polarity of the magnetic state on the tape surface to indicate a binary "1" and the absence of flux change to indicate binary "0". Skew compensation for NRZI is accomplished by introducing time delays in playback electronics such that, at the data output, all tracks change simultaneously, even though some tracks gap will "see" the flux change earlier than others. Because of mechanical tolerances in head and tape manufacture and the time delay skew technique, the practical limit for NRZI recording is 800 Flux changes per inch (FCPI). This translates to a data density of 800 BPI (Bits or Bytes per inch). Standards for data recording densities for NRZI are 200, 556 and 800 BPI and 7 or 9 tracks. Specific format information follows.

11.6.2 RECORDING FORMAT FOR NINE TRACK, 800 BPI TAPE

NRZI recording methods one. Bits are produced by each reversal of flux polarity. Tape is magnetically saturated in each direction. Tape is initially DC erased such that the rim end of the tape is a north seeking pole. The initial gap and any interblock areas as shown in Figure 11.26, Nine Track Data Format, are magnetized so that the north magnetic pole will be toward the BOT marker and the south magnetic pole toward the EOT marker.

The initial gap erased area must begin at least 1.7 inches before the end of the BOT marker and extend a minimum of .5 inches past the BOT marker.



NOTE:

1. CRC (CYCLIC REDUNDANCY CHECX CHARACTER). PARITY OF CRC CHARACTERS IS DETERMINED BY THE NUMBER OF DATA CHARACTERS IN RECORD. ODD NUMBER OF DATA CHARACTERS - EVEN CRC CHARACTER, ETC. CRC USED ONLY IN IBM SYSTEM SYSTEM/360, 800BPI - CRC CHARACTER SPACED FOUR BITS FROM DATA CHARACERS.

2. LRC (LONGITUDINAL REDUNDANCY CHARACTER) ALWAYS ODD PARITY. SPACED FOUR BITS FROM CRC.

3. PARITY BIT (A VERTICAL PARITY BIT IS WRITTEN FOR EACH CHARACTER CONTAINING AN EVEN NUMBER OF BITS).

ACOM/165

Figure 11.26 Data Format - Nine Track

A vertical parity 1 bit is written in channel P for any data byte that contains an even number of 1 data bits. Each byte then will contain an odd number of 1s bits or the recording is in "odd" parity.

A CRC character is written 4 bit spaces after the last charcter of each data block. This character, the chclic redundancy check (CRC) character, is used in 9-track 800 NRZI to correct single-track read errors. The CRC character may be either odd or even parity.

An LRC character is written 8 bit spaces after the last data byte of each block. The longitudinal redundancy check (LRC) character makes each tracks' 1 bit count for the entire block (in the longitudinal direction) an even number. The LRC character itself is written in odd parity. It is used to de tect possible data errors not detected by byte parity checks.

Interblock Gaps (IBGs) or Interrecord Gaps (IRGs) are specified as to length, being 0.60 inches +0.15 - 0.10 inches.

11.6.3 SEVEN TRACK RECORDING FORMATS (800, 556, 200 BPI)

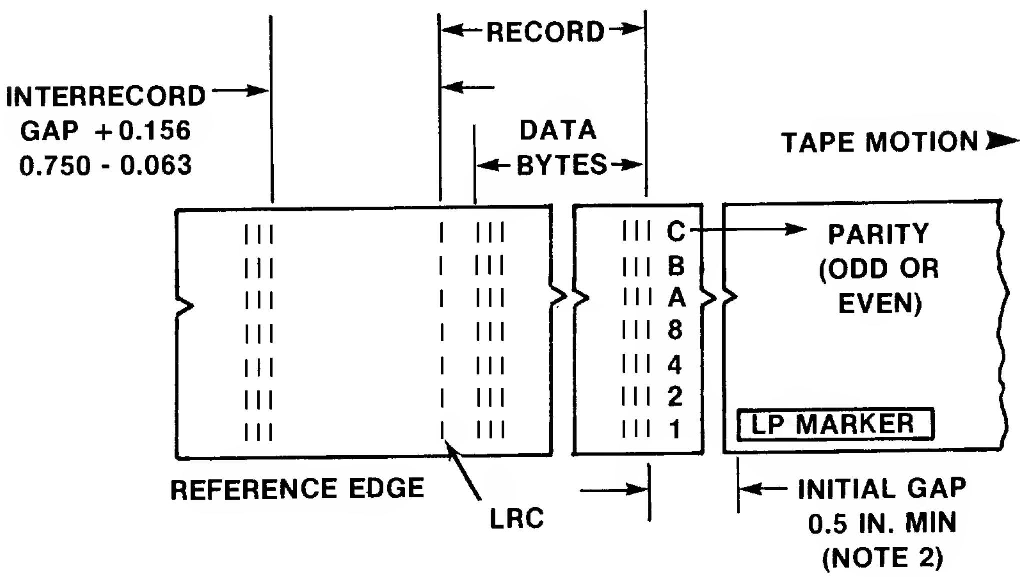
Differences - See Figure 11.27.

Seven track NRZI may be written either odd or even parity.

No CRC Character for 7-track.

LRC character is written 4 bit times after last data byte of block.

IRGs size is specified as 0.750 inches + 0.156 - 0.163 inches.



NOTES:

1. TAPE IS SHOWN WITH OXIDE SIDE DOWN, NRZI RECORDING. BIT PRODUCED BY REVERSAL OF FLUX POLARITY.

2. TAPE TO BE FULLY SATURATED IN THE ERASED DIRECTION IN THE INITIAL GAP AND THE INTERRECORD GAP. ERASURE SUCH THAT A NORTH SEEKING END OF COMPASS WILL POINT TO START OF TAPE.

3. LRC (LONGITUDINAL REDUNDANCY CHECK CHARACTER) ODD OR EVEN-SPACED FOUR BITS FROM DATA CHARACTER.

4. PARITY BIT (A VERTICAL PARITY BIT IS WRITTEN FOR EACH BYTE).

ACOM/166

Figure 11.27 Data Format - Seven Track

11.6.4 FILE MARKS

Following the last data block of a job, or the last block on a tape, a special control block called "File Mark" or Tape Mark is written. See Figure 11.28, 9-Track File Gap Format; and Figure 11.29, 7-Track File Gap Format. The nine track file mark consists of 1 bit for tracks 3, 6, 7 and an identical LRC character 8 bit times later. No CRC character is written.

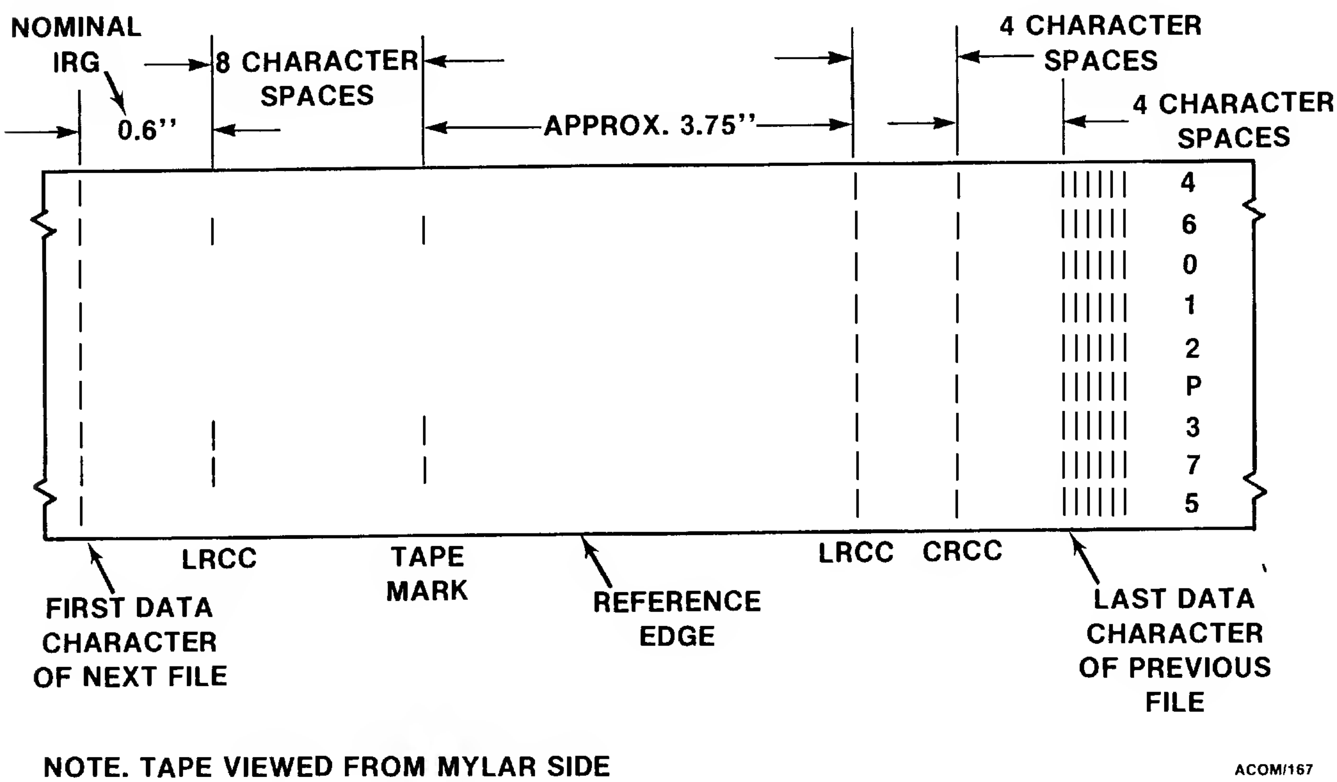


Figure 11.28 9-Track File Gap Format

The seven track filemark consists of 1 bit on tracks 8, 4, 2, and 1 and an identical LRC character 4 bit times later.

11.6.5 P. E. RECORDING

With 800 BPI as the practical upper limit for NRZI recording and the continuing demand for high recording densities, a new recording method was required. Phase Encoding (PE) at 1600 BPI was selected and a tape format was established first by IBM and later adopted by the American National Standards Institute (ANSI) as a proposed standard.

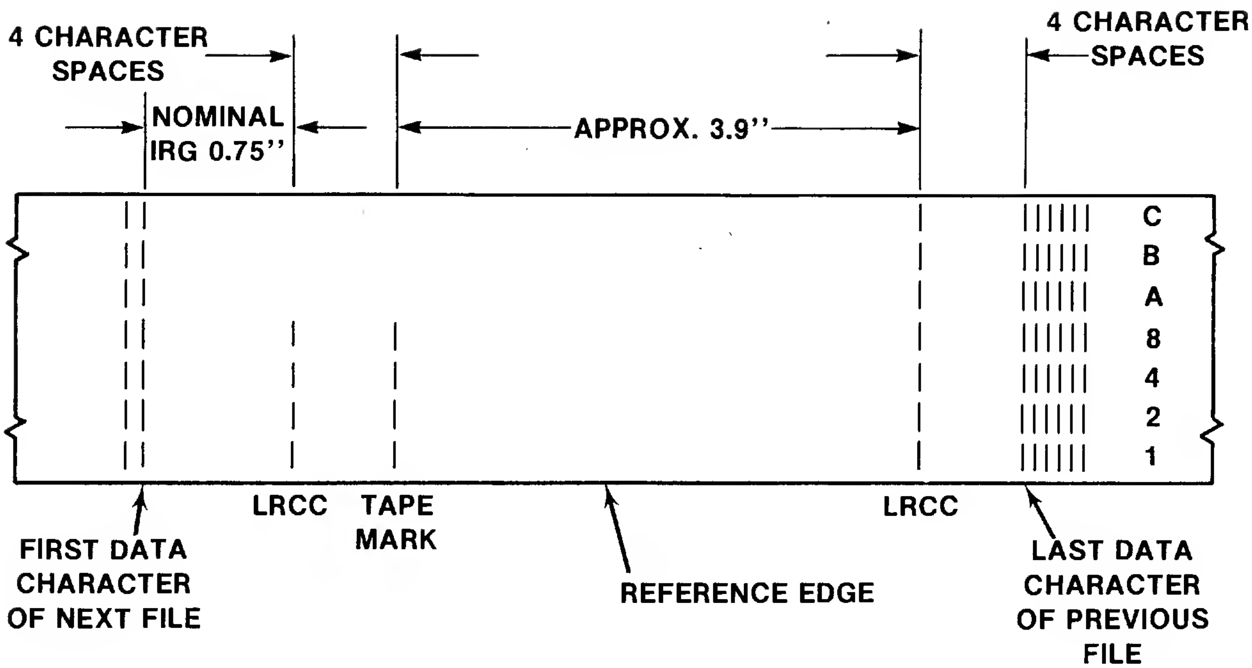


Figure 11.29 7-Track File Gap Format

Tapes are written using magnetic saturation recording. Tape is DC erased with a polarity such that the rim end of the tape is a north seeking pole. A one bit is defined as a flux reversal to reference polarity. A zero bit is defined as a flux reversal toward the opposite polarity. A "phase flux reversal" is written at the nominal midpoint between successive one or zero data bits to establish proper polarity.

The resultant pattern of flux reversals and playback waveforms is shown in Figure 11.30. It can be seen that this method of recording results in two bit densities being recorded, 1600 flux reversals per inch (FRPI) and 3200 FRPI phase shifting of these two frequency components is of the utmost importance to decoding the data on playback.

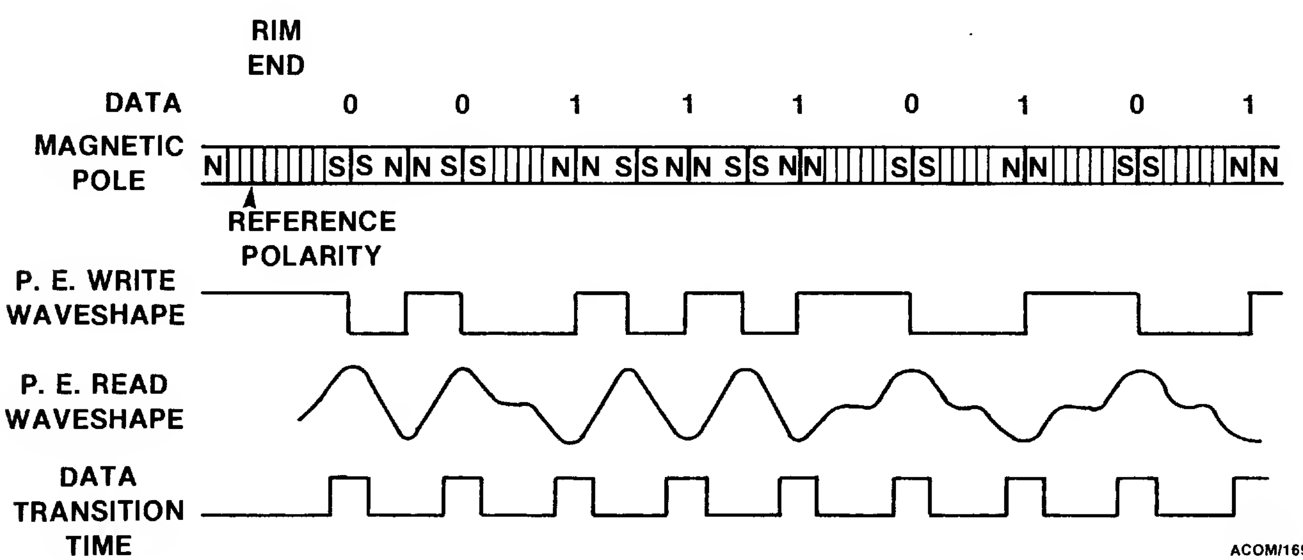


Figure 11.30 P. E. Reversals

11.6.6 PREAMBLE/POSTAMBLE

Reading methods for PE tapes differ from NRZI methods. Following is a general discussion of means employed to extract recorded information in PE. Preambles and postambles are easily identified at the beginning and end of the block (see Figure 11.31). The purpose of the preamble is to allow synchronization of the read electronics with the flux changes before data begins. The preamble is written at 3200 FRPI (all zeros). There are 40 zeros followed by one "all ones" character and following the "all ones character" will be the data.

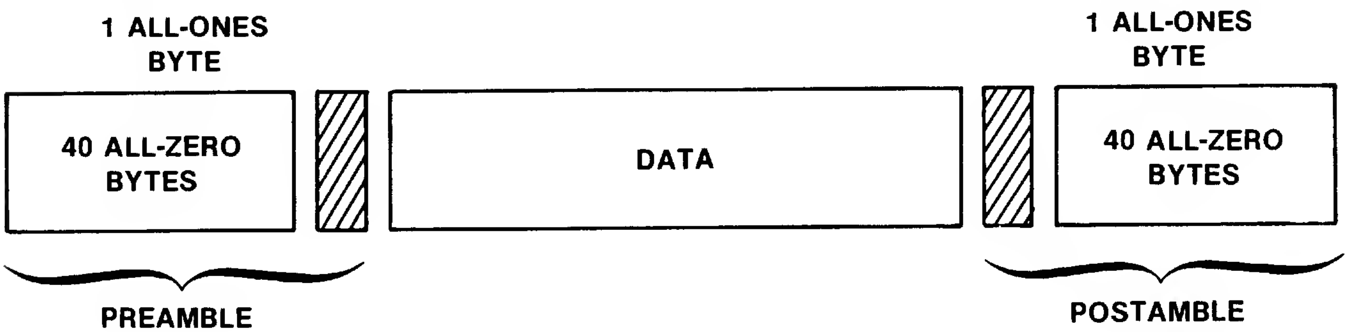


Figure 11.31 Phase-Encoded Tape Block Format

The end of the data is followed by the postamble. This is a mirror image of the preamble. The postamble serves two functions:

1. Indicates the end of data while reading in the forward mode.
2. Serves the same function as the preamble when reading in the reverse mode.

Two conditions should be met before signals are recognized as valid data:

1. Signal must be present in all tracks.
2. A number of zeros must be followed by the "all ones" character of the preamble.

Once detected, the preamble combination of all ones must be treated as a valid character to retain character timing. All zeros is not a valid character unless a single track has been lost. The ones character is not used for data.

The waveform shown as "Data transition time" (see Figure 11.30), is produced by the decoding logic in the PE read electronics. The data transition time signal allows the logic to differentiate between "data bit flux reversals" representing 1s and 0s and any "Phase flux reversals" during the midpoint between data bits. The data transition time signal or "window clock" signal is synchronized to the data on tape during preamble time. Each track synchronizes and detects 1 and 0 bits independently. All

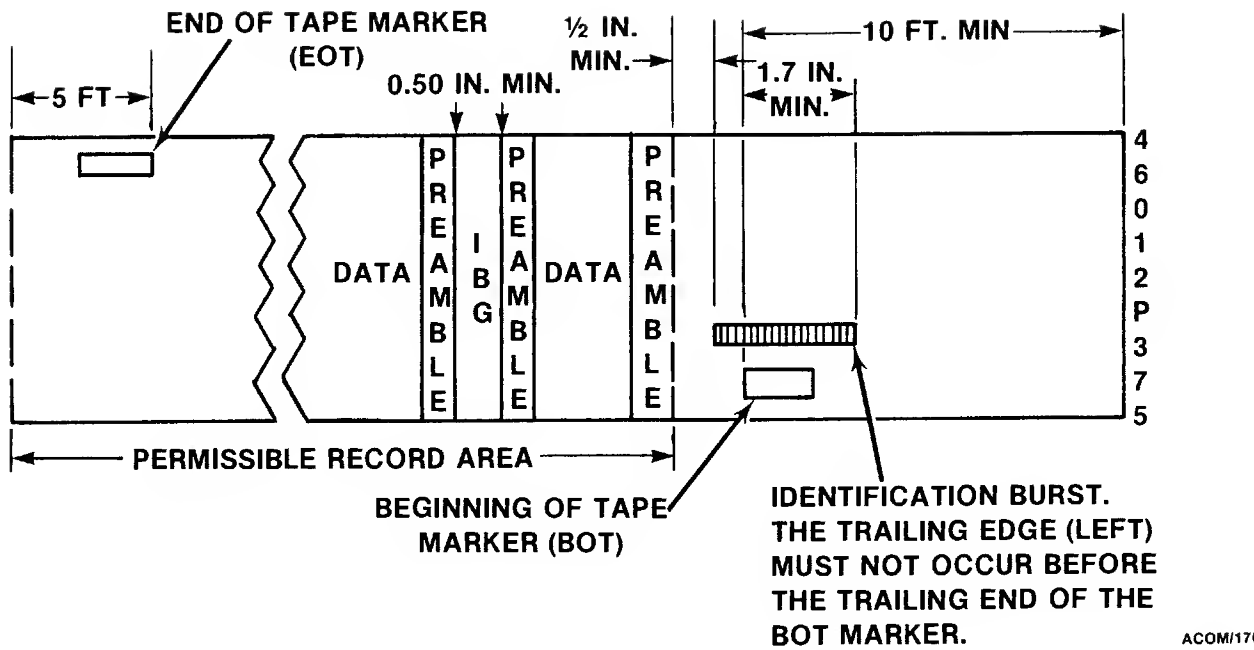


Figure 11.32 P. E. Identification and Gap Format

skew compensation in PE playback is by means of logic rather than time delays and, as such, is not adjustable.

A 1600 BPI P. E. tape is written with an identification burst at load point. This burst consists of 1600 flux reversals per inch in track P, all other tracks erased. The P. E. identification burst must begin at least 1.7 inches before the trailing end of the BOT marker and continue past the BOT marker.

A vertical parity 1 bit is written in track P for all data bytes with an even number of 1s bits. Thus, each byte on tape will be of odd parity.

The data bytes in each block are preceded by a 41 character preamble and the last byte followed by a 41 character postamble. The preamble consists of 40 bytes of zeros in all tracks followed by 1 byte of 1s in all tracks. The postamble is a mirror image, an all 1s byte followed by 40 all 0s bytes.

Interblock Gaps. The size of the Interblock Gap (IBG) is 0.50 inches minimum, 0.60 inches nominal between end of postamble and beginning of following preamble. The first preamble must begin not less than 0.50 inches past the trailing edge of the P.E. identification burst and 0.50 inches from the end of the BOT marker.

P.E. tape mark, or file mark, is any of several combinations of 3200 FRPI on certain channels and DC erasure on others - minimum length is 80 flux reversals in each active track. This is normally preceded by a file gap of 3.75 inches, however, this gap is not specified as part of the standard and may vary. See Figure 11.33.

TRACK	CHANNEL	1	2	3	4	5	6	7*	8
1	5	x	-	x	-	x	-	x	-
2	7	x	x	x	x	x	x	x	x
3	3	-	-	-	-	-	-	-	-
4	P	-	x	x	-	-	x	x	-
5	2	x	x	x	x	x	x	x	x
6	1	-	-	-	-	-	-	-	-
7	0	-	-		x	x	x	x	-
8	6	x	x	x	x	x	x	x	x
9	4	-	-	-	-	-	-	-	-

- dc erased

x recorded at 3200 frpi

* most frequently used combination

Figure 11.33 P. E. Tape Mark Combinations

SECTION XII

USE OF TEST EQUIPMENT

12.1 COMMERCIAL VOLT/OHM METER (VOM)

This discussion refers to the Triplitt 630 VOM meter, but most of the controls and functions described are applicable to VOMs in general.

The VOM (Figure 12.1) provides:

AC and DC voltage ranges of 0-3, 12, 60, 300, 1200, and 6000 volts
Direct-current ranges of 0-6ua, 1.2 ma, 12 ma, 120 ma, and 12 amperes
Resistance ranges of 0-1000Ω, 0-1 megohm, and 100 megohms

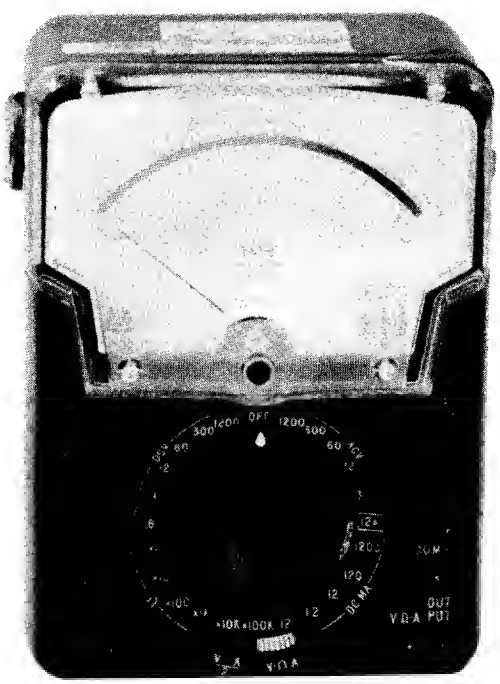


Figure 12.1 Commercial Volt-Ohm-Milliammeter (VOM)

The AC voltage ranges up to 1200 volts rms can also make measurements (for alternating current in the presence of a DC component) through a 0.1 uf blocking capacitor that is self-contained in the VOM.

Voltmeter sensitivity is 20,000Ω-per-volt DC and 5000Ω-per-volt AC. For each of the current ranges, voltage drop is 250 mv at full-scale deflection.

VOM accuracy is 3 percent of full scale on DC voltages and current ranges, except the 6000 volt range where accuracy is within 5 percent of full scale.

VOM Accuracy is 4 percent of full scale on AC ranges except the 6000 volt range where accuracy is 5 percent. VOM accuracy on each of the resistance ranges is 3 percent of scale length.

The twenty position range switch has three poles for setting up the various circuits and ranges. In the off position, poles 1 and 2 connect a short circuit across microameter M to protect the movement against jostling. The other VOM control is Ohms Adjust rheostat R28. A 1-amp fuse F1 protects the meter and circuit from overloading.

The COM terminal is the negative connection for all ranges. For the 6000 volt range, the test leads connect to the COM and 6000 DCV terminals, and the switch is set to 1200-6000. For all other ranges, the test leads are connected to COM and V - -A terminals.

For the 6000 volt range, the test leads connect to COM and 6000 ACV terminals, and the range switch is set to 1200-6000. For output measurements (or separation of the alternating current) the test leads are connected to the COM and OUTPUT terminals.

This circuit has two separate batteries: a 1-½ volt battery (B2) for the X1 (0-1000 ohms), X10 (0-10,000 ohms), and X1000 (0-1meg) ranges, and a 30 volt battery (B1) for the X100,000 (0-100 meg) range. On all ranges, the meter is first set to zero using ADJ rheostat R28 with the test leads shorted together.

12.1.1 VOM OPERATING INSTRUCTIONS

The VOM is a basic tool is electronic measurements. Proper use of the VOM enhances accuracy, increases usefulness, and prolongs instrument life. The following techniques and practices should be used:

1. To prevent meter overload and possible damage when checking currents or voltages, start with the highest range of the instrument and switch down in range successively.

2. For highest accuracy, make the final current or voltage reading on the range in which the deflection falls in the upper half of the meter scale.

3. For maximum accuracy and minimum circuit load, whenever possible, choose a voltmeter range so that the total voltmeter resistance (ohms-per-volt rating x full scale voltage) is at least 100 times the resistance of the circuit under test. This is imporant since the voltage indicated on the VOM was first multiplied by (R1 + R2)/R2 to give the true voltage value. (R1 is the resistance of the circuit under test, and R2 the total voltmeter resistance).

4. Make all resistance readings in the uncrowded portion of the meter scale, whenever possible.

5. Use extraordinary precaution when checking high voltages and also when checking currents in high-voltage circuits. A safe procedure is to turn off power, connect the meter (do not use hand held test leads), switch power on and take reading, switch the power off again before removing meter connections.

6. Verify circuit polarity before making a test. Connect the positive terminal of the meter to the positive terminal of the circuit under test. Either polarity is satisfactory when making AC measurements.

7. When checking resistors in circuits, be sure the power is switched off. A voltage across a resistor may damage the meter.

8. Renew ohmmeter batteries often for accuracy of the resistance scales and to prevent spilling of electrolyte inside the VOM.

9. Reset the Zero Ohms rheostat, with the test leads connected temporarily together, whenever switching to a new resistance range.

10. Set the function switch at AC or DC to correspond with the source under test. If there is a DC component in combination with an AC voltage under test, switch to Output Meter function to put the blocking capacitor in series with the input leads and protect the rectifier and meter. If the VOM has no Output function, a 0.1-1 uf capacitor must be connected in series with one of the test leads. In either case, the meter reading is slightly lower than the true voltage value because of the reactance of the capacitor. The extent of the error depends on the operating frequency. The error is highest at low frequency. After using the Output function, either with an internal or external blocking capacitor, touch the test leads together momentarily to discharge the capacitor.

11. In all measurements, hold the test lead handles near their lead ends, and do not let fingers touch the metallic prod tips. This technique protects from electric shock while measuring voltage or current, and prevents body-resistance shunting error when checking resistance.

12. Use the mechanical zero-set screw to bring the pointer exactly over the zero line when no voltage or current is applied to the meter.

13. Recalibrate the VOM at frequent intervals.

14. When the VOM is idle, switch to the highest DC voltage range and remove the test leads. Never let meter stand by on a resistance range. If the meter has an Off position, switch to this position.

12.1.2 VOM CARE AND TRANSPORTING

The VOM must be protected from dust, moisture, fumes and excessive heat to ensure long term, dependable use.

When transporting the VOM, switch to one of the DC ranges. The low-resistance shunt, which then is in parallel with the meter, acts to damp the movement and prevent excessive swinging which otherwise might damage the moving-coil assembly. The Off position of some meters short-circuits the instrument.

12.2 OSCILLOSCOPE

This discussion refers to the TEKTRONIX Model 465 Oscilloscope, but most of the controls and functions described are applicable to oscilloscopes in general (see Figure 12.2).

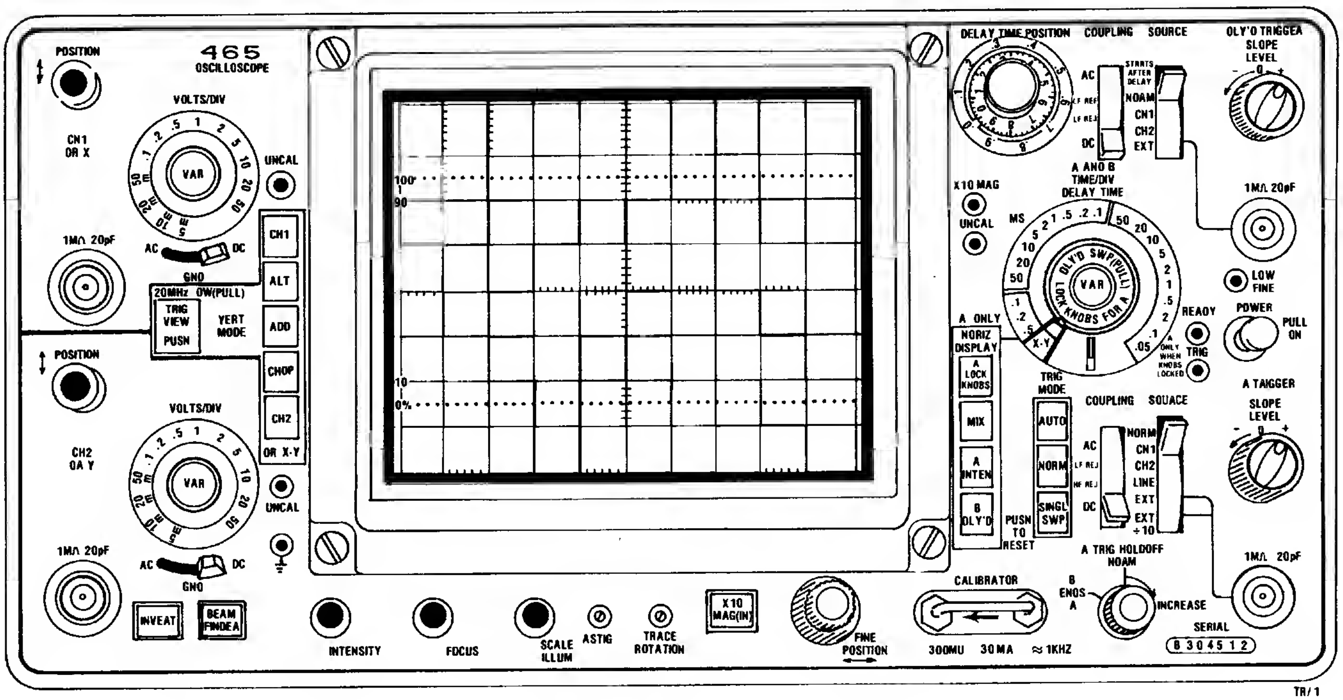


Figure 12.2 Oscilloscope Front Panel

The TEKTRONIX 465 Oscilloscope is a dual-channel, 100 megahertz portable instrument using only solid state and integrated circuit components (except the CRT). The relatively small size and light weight of the 465 make it easy to transport and yet acurately do all necessary high-frequency measurements. The dual-channel DC-to-100 MHz vertical system has calibrated deflection factors from 5-millivolts to 5-volts-per-division. The sweep trigger circuits have stable triggering over the full band-width capabilities of the vertical deflection system. The horizontal deflection system has calibrated sweep rates from 0.5 seconds to 0.05 microsecond-per-division along delayed sweep features for accurate relativ-time measurements. The regulated DC power supplies maintain constant output over a wide variation of line voltage and frequencies. Total maximum power consumption of the oscilloscope is approximately 75 watts.

12.2.1 INTENSITY CONTROL

The INTENSITY control sets the brightness of the display presented on the CRT. The Intensity control should be set to the minimum level that provides a usable display. The setting of the Intensity control may affect the correct focus of the display. Slight readjustment of the FOCUS may be necessary when the intensity level is changed. To protect the CRT phosphor, do not turn the Intensity control higher than necessary to provide a satisfactory display. Be careful that the Intensity control is not set too high when changing the **TIME/DIV** switches from fast to slow sweep rates, or when changing to the X-Y mode of operation.

12.2.2 GRATICULE

The graticule of the 465 oscilloscope is internally marked on the face-plate of the CRT to provide accurate, no-parallax measurements. The graticule is marked with eight vertical and ten horizontal divisions. Each major division is segmented into five minor divisions at the center vertical and horizontal lines. The vertical gain and horizontal timing are calibrated to the graticule so accurate measurements can be made from the CRT display directly.

12.2.3 VERTICAL MODE OF OPERATION

For single-trace displays, either of the input channels can be used. Apply the signal to the desired input connector and set the VERT MODE switch to display the channel used. The trigger SOURCE switches can select either vertical channel as a trigger signal source; however, only Channel 2 has the INVERT function so the correct channel must be selected to take advantage of this feature.

For dual-trace operation (Alternate Mode), the ALT position of the VERT MODE switch produces a display which alternates between Channel 1 and Channel 2 with each sweep of the CRT. Although the ALT mode can be used at all sweep rates, the CHOP mode provides a more satisfactory display at sweep rates below about 50 microsecond-per-division. At these slower sweep rates, alternate mode switching can be seen on the scope presentation.

When triggering in the NORM positon of the trigger SOURCE switches, the sweep is triggered from the signal on each channel. This provides a stable display of two unrelated signals, but does not indicate the time relationship between the signals. In the CH 1 or CH 2 positions of the trigger SOURCE switches, the two signals are displayed showing true time relationship. If the signals are ot time related, one of the signals displayed is unstable.

For dual-trace operation (Chopped Mode), the CHOP position of the VERT MODE switch produces a display which is electronically switched between channels. In general, the **CHOP** mode provides the best display at sweep rates slower than about 50 microseconds-per-division or whenever dual-trace, single-shot phenomena are to be displayed. At faster sweep rates, the chopped switching becomes apparent and may interfere with the display.

Proper internal triggering for the chopped mode of operation cannot be obtained in the NORM positon of the trigger SOURCE switches. If the NORM position is used, the sweep circuits are triggered from

the between-channel switching signal and both waveforms are unstable. External triggering from a signal which is time-related to either signal provides the same result as triggering internally from Channel 1 or Channel 2. Two signals which are time-related can be displayed in the chopped mode showing true time relationship. however, if the signals are not time-related, one signal displayed appears unstable.

Two single-shot, transient, or random signals that take place within the time determined by the TIME/DIV switch (ten times the displayed rate) can be compared using the chopped mode. To get a usable display, the sweep must be triggered from the vertical channel displaying the event that comes first. Since the signals show the true time relationship, time difference measurements can be made.

For algebraic addition, the ADD position of the VERT MODE switch can be used to display the sume or difference of two signals, for common-mode rejection to remove an undesired signal, or for DC offset (applying a DC voltage to one channel to offset the DC component of a signal on the other channel).

The overall deflection factor in the ADD mode when both VOLTS/DIV switches are set to the same position is the same as the deflection factor indicated by either **VOLTS/DIV** switch. The amplitude of an added mode display can be determined directly from the resultant CRT deflection multiplied by the deflection factor indicated by either VOLTS/DIV switch. However , if the CH1 and CH2 VOLTS/DIV switches are set to different deflection factors, the resultant deflection factor is difficult to determine from the CRT display. In this case, the voltage amplitude of the resultant display can be determined accurately only if the amplitude of the signal applied to either channel is known.

The following general precautions should be observed when using the ADD mode:

1. Do not exceed the input voltage rating of the 465.
2. Do not apply signals that exceed an equivalent of about eight time the VOLTS/DIV switch setting. For example, with a VOLTS/DIV switch setting of 0.5, the voltage applied to that channel should not exceed about four volts. Larger voltages may distort the display.
3. Use CH1 and CH2 POSITION control settings which most nearly position the signal of each channel to mid-screen when viewed in either the CH1 or CH2 position of the VERT MODE switch. This ensures the greatest dynamic range for ADD mode operation.
4. For similar response from each channel, se the CH1 and CH2 Input Coupling switches to the same position.

12.2.3.1 Deflection Factor - The amount of vertical deflection produced by a signal is determined by the signal amplitude, the setting of the VOLTS/DIV switches, and the setting of the VOLTS/DIV VAR controls. The calibrated deflection factors indicated by the VOLTS/DIV switches apply only when the V8LTS/DIV VAR controls are set to the calibrated position (detent fully clockwise).

The VOLTS/DIV VAR controls provide continuously variable (uncalibrated) vertical deflection factors between the calibrated settings of the VOLTS/DIV switches. The VOLTS/DIV VAR controls extend the maximum vertical deflection factor of the 465 to at least 12.5 volts per division (5 volts position).

12.2.3.2 Ground Considerations - Reliable signal measurements cannot be made unless both the oscilloscope and the unit udner test are connected together by a common reference (ground) lead in addition to the signal lead or probe. The ground strap on the signal proble provides the best ground. Also, a ground lead can be connected to the 465 chassis ground banana jack to establish a common ground with the signal source.

12.2.3.3 Input Coupling - The Input Coupling switches allow a choice of coupling methods for the applied signal. The type of display desired and the applied signal determines the coupling method to use.

In the AC coupling position, the DC component of the signal is blocked by a capacitor in the input circuit. The low-frequency attenuation can be expected near this frequency limit. Attenuation in the form of waveform tilt also appears in square waves which have low-frequency components. The AC coupling position provides the best display of signals with a DC component which is much larger than the AC component.

The DC coupling position can be used for most applications. This position lets you measure the DC component of a signal and must be used to display signals below about 20 hertz to avoid the attenuation that would occur using AC coupling.

The GND position provides a ground reference at the input of the 465 without the need to externally ground the probe. The signal applied to the probe is internally disconnected from the input circuit and connected to ground through a one-megohm resistor. The amplifier input circuit is held at ground potential.

In the GND position, connecting the input signal to ground through a one-megohm resistor forms a pre-charging network. This network allows the Input Coupling capacitor to charge to the average DC voltage level of the signal applied to the probe. Since this takes place in the GND position of the Input Coupling switch, any large voltage transients accidentally generated are not applied to the amplifier input. The pre-charge network also provides a measure of protection to the external circuitry by reducing the current levels that can be drawn from the external circuitry during capacitor charging. The following procedures should be used whenever the probe tip is connected to a signal source having a different DC level than that previously applied.

1. Before connecting the probe tip to a signal source, set the Input coupling to GND.

2. Touch the probe tip to oscilloscope chassis ground. Wait several seconds for the Input Coupling capacitors to discharge.

3. Connect the probe tip to the signal source.

4. Wait several seconds for the Input Coupling capacitor to charge.

5. Set the Input Coupling to AC. The display remains on screen so the AC component of the signal can be measured in the normal manner.

12.2.3.4 Trigger Source - For internal triggering in most applications, the sweep can be triggered immediately. In the **NORM, CH1**, and **CH2** positions of the trigger **SOURCE** switches, the trigger signal is obtained from the vertical deflection system. For single-trace displays of either channel the NORM position provides the most convenient operation. However, for dual-trace displays, special considerations must be made to provide the correct display. Refer to the Dual-Trace Operation explanation in the Vertical Mode of Operation portion of the General Operating Instructions for dual-trace triggering information.

For line triggering, the A Trigger SOURCE switch has a LINE position that the B Trigger SOURCE switch does not have. The LINE position connects a sample of the power-line voltage to the input of the A Trigger Generator. Line triggering is useful when the input signal is time-related (multiple or sub-multiple) to the line frequency. It is also useful for providing a stable display of a line-frequency component in a complex waveform.

For external triggering, an external signal connected to the external trigger input connector can be used to trigger the sweep in the eXT and eXT 10 positions of the SOURCE switches. The external signal must be time-related to the displayed signal for a stable display. An external trigger signal can be used to provide a triggered display when the internal signal is too low in amplitude for correct triggering, or contains signal components on which it is not desired to trigger. It is also useful when signal tracing in amplifiers, phase-shifted networks, wave-shaping circuits, etc. The signal from a single point in the circuit under test can be connected to the external trigger input connector through a cable or signal probe. The sweep is then triggered by the same signal at all times and allows amplitude, time relationship, or waveshape changes of signals at various points in the circuit to be examined without resetting the trigger controls.

For B starts after delay time, in the STARTS AFTER DELAY position of the B SOURCE switch, the B Sweep is triggered to run immediately after the delay time. The setting of the DELAY-TIME POSITION control determines the amount of delay time after the start of A Sweep. Since the amount of delay time is the same for each sweep, B Sweep starts at the same point each time and the display appears stable.

12.2.3.5 Trigger Coupling - Four methods of coupling the trigger signal to the trigger circuits can be selected with the trigger COUPLING switches. Each position lets you select or reject certain frequency components of the trigger signal to get selective triggering.

For AC coupling, the AC position blocks the DC component of the trigger signal. Signals with low-frequency components below about 30 hertz are attenuated. In general, AC coupling can be used for most applications. However, if the trigger signal contains unwanted frequency components or if the sweep is to be triggered at a low repetition rate or a DC level, one of the remaining COUPLING switch positions provides a better display.

For low-frequency reject, the LF REJ position passes all high-frequency signals above about 15 kilohertz. DC is rejected and signals below about 15 kilohertz are attenuated. When triggering from complex waveforms, this position is useful for provide stable display of the high-frequency components.

DC coupling is used to provide stable triggering with low-frequency signals which would be attenuated in the other positions, or with low-repetition rate signals. The LEVEL control can be adjusted to provide triggering at the desired DC level on the waveform. When triggering in the NORM position of

the SOURCE SWITCH, the setting of the CH1 and CH2 POSITION controls affect the DC triggering level.

DC trigger coupling should not be used in the ALT dual-trace mode if the trigger SOURCE switch is set to NORM. If used, the sweep triggers on the DC level of one trace and then either locks out completely or free runs on the other trace. Correct DC triggering for this mode can be obtained only with the trigger SOURCE switch set to some position other than NORM.

12.2.3.6 Trigger Slope - The trigger SLOPE switch determines whether the trigger circuit responds on the positive-going or negative-going portion of the trigger signal. When the SLOPE switch is in the + (positive-going) position, the display starts with the positive-going portion of the waveform; in the - (negative-going) position, the display starts with the negative-going portion of the waveform. When several cycles of a signal appear in the display, the setting of the SLOPE switch is often unimportant. However, if only a certain portion of a cycle is to be displayed, correct setting of the SLOPE switch is important to provide a display which starts on the desired slope of the input signal.

12.2.3.7 Trigger Level - The trigger LEVEL control determines the voltage level on the triggering waveform at which the sweep is triggered. When the LEVEL control is set in the + region, the trigger circuit responds at a more positive point on the trigger signal. When the LEVEL control is set in the -region, the trigger circuit responds at a more negative point on the trigger signal. To set the LEVEL control, first select the trigger, SOURCE, COUPLING, and SLOPE. Then set the LEVEL control fully clockwise and rotate it counterclockwise until the display starts at the desired point.

12.2.3.8 A Sweep Triggered Light - The A Sweep TRIG light provides a conventient indication of the condition of the A Trigger circuit. If the A Trigger controls are correctly adjusted with an adequate trigger signal applied, this light is on. However, if the A LEVEL control is misadjusted, the A COUPLING or A SOURCE switches incorrectly set, or the trigger signal too low in amplitude, the A Sweep TRIG light is off. This feature can be used as a general indication of correct triggering. It is particularly useful when setting up the trigger circuits when a trigger signal is available without a trace display on CRT. It also indicates that the A Sweep is correctly triggered when operating in the B (delayed) Sweep mode.

12.2.3.9 A Trigger Mode - For automatic triggering, the AUTO position of the A TRIGGER MODE switch provides a stable display when the A LEVEL control is correctly set (see Trigger Level portion of General Operating Information) and an adequate trigger signal is present. The A Sweep TRIG light indicates when the A Sweep Generator is triggered.

When the trigger repetition rate is less than about 20 hertz or in the absence of an adequate trigger signal, the A Sweep Generator free runs to produce a reference trace. When an adequate trigger signal is again applied, the free-running condition ends and the A Sweep Generator is triggered to produce a stable display (with the correct LEVEL control setting).

For normal triggering, operation in the NORM position of the A TRIG MODE switch is the same as in the **AUTO** position when a trigger signal is applied. However, when a trigger signal is not present, the A Sweep Generator remains off and there is no display. The A Sweep TRIG light indciates when the A Sweep Generator is triggered.

Use the NORM mode to display signals with repetition rates below about 20 hertz. This mode provides an indication of an adequate trigger signal as well as the correctness of trigger control settings, since there is no display without proper triggering. Also, the A Sweep TRIG light is off when the A Sweep is not correctly triggered.

Single sweep is used when the signal to be displayed is not repetitive or varies in amplitude, shape, or time, so that a conventional display may produce an unstable presentation. To avoid this, use the single-sweep feature of the 465. The single-sweep mode can also be used to photograph a non-repetitive signal.

To use the single-sweep mode, first make sure the trigger circuit responds to the event to be displayed. Set the A TRIG MODE switch to AUTO or NORM and obtain the best possible display in the nrmal manner (for random signals set the trigger circuit to trigger on a signal which is approximately the same amplitude and frequency as the random signal). Then set the A TRIG MODE switch to SING SWP and press the PUSH TO RESET button. When the PUSH TO RESET button is pushed, the next trigger pulse initiates the sweep and a single trace is presented on the screen. After this sweep is complete, the A Sweep Generator is "locked out" until reset. The READY indicator lights when the A Sweep Generator circuit has beenset and is ready to produce a sweep; it goes out after the sweep is complete. To prepare the circuit for another single-sweep display, press the PUSH TO RESET button again.

12.2.3.10 A Trigger Holdoff - The A TRIGGER HOLDOFF control provides the ability to obtain stable triggered displays when triggering on periodic or irregular signals (such as complex digital words). To use the control, first obtain the most stable presentation possible by adjusting the remainder of the A Trigger controls in the normal manner. Now, rotate the A TRIG HOLDOFF control clockwise until any remaining instability is eliminated.

In the **B ENDS A** (fully clockwise) position of the control, A Sweep is reset at the end of B Sweep. This provides the fastest sweep repetition rate when operating in a delayed sweep mode which, in turn, provides maximum display intensity (useful when viewing low repetition rate signals).

12.2.4 HORIZONTAL MODE OF OPERATION

There are basically two modes of operation for the internal horizontal sweep system. These are delayed and non-delayed. X-Y operation is reserved for discussion at a later time.

For non-delayed mode, in the A position of the HORIZ DISPLAY switch, the time base displayed is the A Time Base derived from the A Sweep Generator. The sweep rate of the display is determined by the setting of the A TIME/DIV switch. This is the only non-delayed mode of operation.

For delayed mode, the B Sweep (delayed sweep) is operable in the MIX, A INT, and B DLY'D positions of the HORIZ DISPLAY switch. The A Sweep rate along with the DELAY-TIME POSITION dial setting determines the time that the B Sweep is delayed. The sweep rate of the delayed portion is determined by the B TIME/DIV switch setting.

In the A INT position, the time base displayed is the A Time Base as in the Non-Delayed Mode but, additionally, it is intensified or brightened along some portion of its length. The intensification

coincides with the time the B Sweep is running and is approximately equal to 10 times the setting of the **B TIME/DIV** switch. The amount of delay time between the start of A Sweep and the intensified portion is determined by the setting of the **A TIME/DIV** switch and the **DELAY-TIME POSITION** dial.

When the HORIZ DISPLAY switch is set to B DLY'D, only the intensified portion (as viewed in the A INT position) is displayed on the screen at the sweep rate indicated by the B TIME/DIV switch.

The MIX position of the HORIZ DISPLAY switch provides a CRT display containing more than one time factor on the horizontal axis. The first part of the display is at a sweep rate set by the A TIME/DIV switch and for a time duration determined by the setting of the DELAY-TIME POSITION control. The latter part of the display is at a sweep rate set by the B TIME/DIV switch.

12.2.4.1 Horizontal Sweep Rates - The A and B TIME/DIV and DELAY TIME switches select calibrated sweep rates for the Sweep Generators. The A VAR control provides continuously variable sweep rates between the settings of the A TIME/DIV switch. Whenever the UNCAL light is on, the sweep rate of the A Sweep Generator is uncalibrated. The light is off when the AVAR control is set to the calibrated detent.

The sweep rate of the A Sweep Generator is bracketed by the two black lines on the clear plastic outer flange of the **TIME/DIV** switch. The B Sweep Generator sweep rate is indicated by the dot on the **B TIME/DIV** knob. When the dot on the inner knob is set to the same position as the lines on the outer flange, the two lock together and the sweep rate of both sweep generators is changed at the same time. However, when the **B TIME/DIV** knob is pulled outward, the outer flange is disengaged and only the B Sweep Generator sweep rate is changed. This allows changing the delayed sweep rate without changing the delay time determined by the A Sweep Generator.

The accurancy specifications for the horizontal sweeps apply over the full ten horizontal divisions. Therefore, accurate time measurements do not have to be limited to the center graticule divisions but can be made anywhere within the graticule area.

12.2.4.2 Sweep Magnification - The sweep magnifier expands the sweep by a factor of ten. The center division of the unmagnified display is the portion visible on the screen in magnified form. The equivalent length of the magnified sweep is more than 100 divisions. Any 10-division portion of the magnified sweep can be viewed by adjusting the horizontal POSITION control to bring the desired portion into the viewing area.

To use the magnitifed sweep, first move the portion of the display which is to be expanded to the center of the graticule. Then set the X10MAG switch to the on (button in) position. Use the horizontal POSITION control to move the magnified portion to the desired position. The X10MAG indicator light located to the elft of the TIME/DIV switch is on whenever the magnifier is on.

When the X10 MAG switch is set to on, the sweep rate is determined by dividing the TIME/DIV switch setting by 10. For example, if the TIME/DIV switch is set to 0.50us, the magnified sweep rate is 0.05 microsecond/division. The magnified sweep rate is a calibrated sweep rate when the UNCAL light is off, and must be used for all time measurements when the X10 MAG switch is set to on.

12.2.4.3 X-Y Operation - In some applications, it is desirable to display one signal versus another (X-Y) rather than against time (internal sweep). The X-Y position (fully counterclockwise) of the A and B TIME/DIV switch provides a means for applying an external signal to the horizontal amplifier for this type of display.

When the TIME/DIV switches are fully counterclockwise to the X-Y position, the horizontal (X-axis) deflection is provided by the signal connected to the **CH1** or **X** input connector and the vertical deflection is provided by the signal connected to the CH2 or Y input connector (CH2 pushbutton must be pressed). The calibrated X-axis deflection is indicated by the CH1 VOLTS/DIV switch; calibrated Y-axis deflection is indicated by the CH2 VOLTS/DIV switch. For X-Y operation, the Horizontal POSITION CONTROL provides X-axis positioning and the CH2 POSITION control provides Y-axis positioning.

Do not exceed the horizontal scan area of the graticule in the X-Y mode of operation. This mode can be used to measure phase differences of signals up to about 50 kilohertz in frequency. Above this frequency, the inherent phase shift in the system makes phase measurement difficult.

12.2.4.4 Output Signals - The A and B + GATE output connectors (on instrument rear panel) provide a positive-going rectangular output pulse coincident with the sweep time of the respective sweep generator. This rectangular pulse is about five volts in amplitude (into high-impedence loads) with a pulse duration the same as the respective sweep.

The CH1 VERT SIGNAL OUT connector provides a sample of the signal connected to the CH1 or X input connector. Output amplitude is approximately 50 millivolts per division of display deflection when connected to a high-impedence load (25 millivolts per division into a 50 load).

12.2.4.5 Intensity Modulation - Intensity (Z-axis) modulation can be used to relate a third item of electrical phenomena to the vertical (Y-axis) and the horizontal (X-axis) coordinates without affecting the waveshape of the displayed signal. The Z-axis modulating signal applied to the CRT circuit changes the intensity of the displayed waveform to provide this type of display. "Gray scale" intensity modulation can be obtained by applying signals which do not completely blank the display. Large amplitude signals of the correct polarity completely blanks the display. The sharpest display is provided by signals with a fast rise and fall. The voltage amplitude required for visible trace modulation depends on the setting of the INTENSITY control. At normal intensity level, a five-volt peak-to-peak signal produces a visible change in brightness.

Time markers applied to the EXT Z AXIS input connector provide a direct time reference on the display. With uncalibrated horizontal sweep or X-Y mode operation, the time markers provide a means of reading time directly from the display. However, if the markers are not time-related to the displayed waveform, a single-sweep diaplay should be used (for internal sweep only) to provide a stable display.

12.2.4.6 Calibrator - The one-kilohertz square-wave Calibrator of the 465 provides a convenient signal source for checking basic vertical gain. The Calibrator output signal is also very useful for adjusting probe compensation.

The Calibrator provides an accurate peak-to-peak square-wave voltage of 0.3 volts. The output resistance of the circuit is low enough to almost totally eliminate the effects of external loading. The

output voltage is accessible by touching the tip of the probe to the current loop available on the front panel of the instrument.

The current loop provides a 30 milliampere peak-to-peak square-wave current which can be used to check and calibrate current-measuring probe systems. This current signal is obtained by clipping the probe around the current loop. The arrow by the probe loop indicates conventional current flow from + to −.

The repetition rate of the output signal is approximately one kilohertz. The accuracy is not exact enough to allow the signal to be used for more than approximate horizontal timing.

The square-wave output signal of the Calibrator can be used as a reference wave shape when checking or adjusting the compensation of passive, high-resistance probes. Since the square-wave output from the Calibrator has a flat-top, any distortion in the displayed waveform is due to misadjustment of probe compensation.

12.2.4.7 Obtaining Basic Displays - The following instructions let an operator who is not familiar with the 465 get the basic displays commonly used. Before proceeding with these instructions, set the instrument controls as follows:

- **VERTICAL CONTROLS**

VERT MODE Switch	CH1
VOLTS/DIV Switches	Proper Position determined by amplitude of signal to be applied.
VOLTS/DIV VAR Controls	Calibrated detent
Input Coupling Switches	AC
Vertical POSITION Controls	Midrange
20 MHz BW Switch	Not limited
INVERT Switch	Button out
INTENSITY Control	Fully counterclockwise
FOCUS Control	Midrange
SCALE ILLUM Control	Midrange

- **TRIGGER CONTROLS (both A/B if applicable)**

SLOPE Switch	+
LEVEL Control	0
SOURCE Switch	NORM
COUPLING Switch	AC
TRIG MODE Switch	AUTO
A TRIG HOLDOFF Control	NORM

- HORIZONTAL SWEEP **CONTROLS**

TIME/DIV Switches	Locked together at 1 ms
A TIME/DIV VAR	Calibrated detent
X10 MAG Switch	Off (Button out)
POSITION Control	Midrange

12.2.4.8 Normal Sweep Display - To get a normal sweep display:

a. Set the POWER switch to on (button out). Allow several minutes for instrument warmup.

b. Connect the external signal to the CH1 input connector.

c. Advance the INTENSITY control until the display is visible. If the display is not visible with the INTENSITY control at mid-range, press the BEAM FIND pushbutton and adjust the CH1 VOLTS/DIV switch until the display is reduced in size vertically; then center the compressed display with the vertical and horizontal POSITION controls; release the BEAM FIND pushbutton. Adjust the FOCUS control for a well-defined display.

d. Set the CH1 VOLTS/DIV switch and CH1 POSITION control for a display which remains in the display area vertically.

e. Adjust the A Trigger LEVEL control for a stable display.

f. Set the A TIME/DIV switch and the horizontal POSITION control for a display which remains in the display area horizontally.

12.2.4.9 Magnified Sweep Display - To get a magnified sweep display:

a. Preset the instrument controls and follows steps a through f for obtaining a Normal Sweep Display (previous paragraph).

b. Adjust the horizontal POSITION control to move the area to be magnified to within the center graticle division of the CRT. If necessary, change a TIME/DIV switch setting so the complete area to be magnified is within the center division.

c. Set the X10 MAG switch to the on position (button in) and adjust the horizontal POSITION control for precise positioning of the magnified display.

12.2.4.10 Delayed Sweep Displays - To get delayed sweep displays:

a. Preset the instrument controls and follow steps a through f for obtaining a Normal Sweep Display (paragraph 12.2.4.8).

b. Set the HORIZ DISPLAY switch at A INT and the B Trigger SOURCE switch to STARTS AFTER DELAY.

c. Pull out the B TIME/DIV switch knob and turn clockwise so the intensified zone on the display is the desired length. Adjust the INTENSITY control to achieve the desired display brightness.

d. Adjust the DEALY-TIME POSITION dial to position the intensified zone to the portion of the display to be delayed.

e. Set the HORIZ DISPLAY switch to B DLY'D. The intensified zone on the display noted in step C is now being displayed in delay form. The delayed sweep rate is indicated by the dot on the B TIME/DIV switch knob.

f. For a delayed sweep display that exhibits less jitter, set the B Trigger SOURCE switch to the same position as the A Trigger SOURCE switch and adjust the B Trigger LEVEL control for a

stable display. If the A Trigger SOURCE switch is in the LINE position, a sample of the line voltage has to be supplied to the B Trigger circuit externally.

12.2.4.11 Mixed Sweep Display - To get a mixed sweep display:

a. Preset the instrument controls and follow steps a through f for obtaining a Normal Sweep Display (paragraph 12.2.4.8).

b. Pull out on the B TIME/DIV switch knob and turn clockwise to the desired sweep rate. Adjust the INTENSITY control to achieve the desired display brightness.

c. Set the HORIZ DISPLAY switch to MIX. The CRT display now contains more than one time factor on the horizontal axis. The first portion of the display is at the A Time Base sweep rate and the latter part is at the B Time Base sweep rate. The start of the B Time Base portion of the display can be changed by adjusting the DELAY-TIME POSITION control.

12.2.4.12 X-Y Display - To get an X-Y display:

a. Preset the instrument controls and turn the instrument power on. Allow several minutes for instrument warm-up.

b. Set the TIME/DIV switch to X-Y and the VERT MODE to CH2. Apply the vertical signal to the CH2 or Y input connector and the horizontal signal to the CH1 or X input connector. The CH2 POSITION control provides vertical positioning and the Horizontal POSITION control provides horizontal positioning.

c. Advance the INTENSITY control until the display is visible. If the display is not visible with the INTENSITY control at mid-range, press the BEAM FIND pushbutton and adjust the CH1 and CH2 VOLTS/DIV switches until the display is reduced in size both vertically and horizontally; then center the compressed display with the POSITION controls; release the BEAM FIND pushbutton. Adjust the FOCUX control for a well-defined display.

12.2.4.13 Operator Calibration - To check oscilloscope accuracy before use, the TRACE ROTATION should be adjusted, the vertical gain should be set, and the probes should be compensated. The following are procedures for checking the basic measurement capabilities of the 465.

12.2.4.13.1 Trace Rotation Adjustment - Use steps 1 through 3 of the procedure for obtaining a Normal Sweep Display. Set the appropriate Input Coupling switch to GND so the display consists of an undeflected free-running trace. Adjust the TRACE ROTATION adjustment (located on the front panel below the CRT) to align the trace with the center horizontal graticule line.

12.2.4.13.2 Vertical Gain Setting - Obtain a Normal Sweep Display presentation of the calibrator square-wave voltage. Set the appropriate VOLTS/DIV switch to the 50mV position and the Input Coupling to DC. Adjust the appropriate Channel GAIN adjustment for exactly 6 divisions of vertical deflection. Repeat this procedure for the other vertical channel.

12.2.4.13.3 Probe Compensation - Variations in total input capacitance and resistance occur with different combinations of oscilloscopes and probes. Therefore, most attenuator probes are equipped with adjustments to ensure optimum measurement accuracy.

For probe compensation, obtain a Normal Sweep Display presentation on the calibrator square-wave voltage. Set the appropriate VOLTS/DIV switch to the 1 V position and the Input Coupling to DC. Check the waveform presentation for overshoot or rolloff, and readjust compensation for flat tops on the waveforms if necessary.

SECTION XIII

TROUBLESHOOTING TECHNIQUES

13.1 FAMILARITY WITH MACHINE

Troubleshooting, as the word implies, involves analyzing a failed or malfunctioning device to determine the cause of the failure.

One of the best aids to locating a problem is familiarity with the way the device works when no problems are present. The first goal of a Service Representative should be to become as proficient as possible in the operation of all devices which he must maintain. Often familiarity with proper operation of the machine will allow the Service Representative to rapidly resolve customer problems which are due to improper operation procedures. Also, by knowing how the machine should work, it is often possible to observe symptoms which help to identify the problem and eliminate some areas of the machine as probable causes of the problem.

Also, if possible, break the system down to its simplest form. That is, in some systems it is possible to remove such things as logic cards, power supplies, form flash units, etc. These items might not be used for some modes of operation but can still affect the overall system. See if the system can run without it. Remove it to see if it is causing the problem.

For many machines, additional aids are available. One such aid is flowcharts which describe the sequence of events or actions which the device performs to accomplish its normal functions. Flowcharts often aid in finding the action or actions which the device is unable to accomplish, thus leading to an avenue of approach to the fault.

Once a fault or approach is determined, some sort of logical procedure must be followed to isolate the fault(s). Areas which must be included as things to check are:

13.1.1 PHYSICAL INSPECTION

Physical inspection involves looking for loose wires, plugs, nicked cables, burnt components, jammed mechanisms, incorrect switch settings, etc. (i.e., faults with obvious physical indications).

13.1.2 VERIFICATION OF CORRECT POWER SUPPLY VOLTAGES

This step is of the utmost importance for persistent problems. It is important to take nothing for granted, i.e., check both source and point of usage for power. Look for weak, faulty or intermittent

connections which may be sensitive to vibrations or temperature changes. It may be necessary to track all the way back to the point where power enters the building or even beyond.

13.1.3 INTERMITTENT PROBLEMS

Intermittent problems may be due to some external cause such as location, temperature, light, improper use, or to electrical causes such as loading of the power input, surges, or noise on power input, strong electromagnetic signal sources such as arcing contacts, radio or radar transmissions. Obviously, many similar sources of noise can be originated within the equipment experiencing the problem.

13.1.4 SIGNAL TRACING

With a definite problem identified, tracing the signal(s) responsible for the desired action may prove helpful. It must be remembered that very often digital logic may require several coincident conditions to produce the desired outcome. In other words, seeing activity in all the signals contributing to an action proves nothing in itself unless the coincidence of the active states is correct. Know what you are looking for, then check carefully to see if you have it. If you find a signal which you suspect as being bad, check it and those contributing to it very carefully, then double check your work. On a packed logic plane, it is very easy to inadvertently get on a wrong test point and lead yourself down the wrong path.